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# TRANSACTIONS

OF THE

# ROYAL SOCIETY OF EDINBURGH.

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OF

# EDINBURGH.

VOL. XLVI.

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EDINBURGH:

PUBLISHED BY ROBERT GRANT & SON, 107 PRINCES STREET,
AND WILLIAMS & NORGATE, 14 HENRIETTA STREET, COVENT GARDEN, LONDON.

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(Read May 20, 1907. MS. received August 23, 1907. Issued separately January 10, 1908.)

The glaciation of East Lothian has already been dealt with separately by Professor John Young, who, when attached to the Geological Survey, treated this subject in the memoir of the district published in 1866. His account of the phenomena, striæ, boulder clay, dry valleys, etc., is concise and clear, but he does not enter deeply into a discussion of causes. A guarded reference to submersion to account for the presence of an erratic boulder of carboniferous sandstone at a height of 1500 feet above sea-level shows in fact that he had not arrived at a full conception of the possibilities involved in glaciation by land ice. He was, however, quite definite in ascribing many important erosion effects in the district to the work of an "ice-stream." In this as in most other points he had been forstalled by Sir Archibald Geikie,† who had already described the immediately adjoining area to the south.

Since Dr Young's time no one has made a special study of the district. In common with the rest of Scotland, our knowledge has of course advanced with increased experience won in more extended fields. The writings especially of Sir Archibald and Professor James Geikie have fully shown the connection of the local phenomena of the county with the wider problems involved in the glaciation of the country considered as a whole. With regard to the results produced by the flow of land ice across the district we find but little that is new to add.

It is different, however, in respect to the phenomena of the retreat of the ice sheet. These have never been referred to in other than indefinite terms so far as this particular region is concerned. The special feature of our communication is therefore the treatment of this part of the subject.‡ As the historical development of research in this direction has, however, been recently discussed in some detail,§ we have not thought it necessary to re-state it here.

We must further express our indebtedness to various members of the Geological

* Published, so far as Mr Bailey's observations are concerned, by permission of the Director of H.M. Geological Survey.

† *Geology of East Berwickshire*, 1863.

‡ J. Geikie has already given illustrations of the main phenomena which accompany the retreat of an ice-sheet from a hilly country. *Great Ice Age*, 1894, ch. xiv.

§ P. F. Kendall, *A.G.J.S.*, 1902, p. 471, "A System of Glacier Lakes in the Cleveland Hills."

Survey staff who have mapped or revised the drift of this area. Foremost among these is Dr PEACH, whose earliest experience of survey work was gained in East Lothian under Dr YOUNG. He probably was the first to realise that the Lammermuirs had been completely overwhelmed by land ice, and as he worked for several years, at a later date, in the area lying south of the watershed, he was able to establish the point beyond any doubt. His experience in this and other matters has always been at our disposal. The same may be said of Messrs CLOUGH, HINXMAN, MUFF, and CRAMPTON, who have been engaged in the revision of the area for the Geological Survey, and in close connection with whom one of ourselves has been acting. We would further observe that Mr BARROW has simultaneously been employed in investigating the allied problems of the Garleton Hills, which are situated in East Lothian, but which constitute a naturally

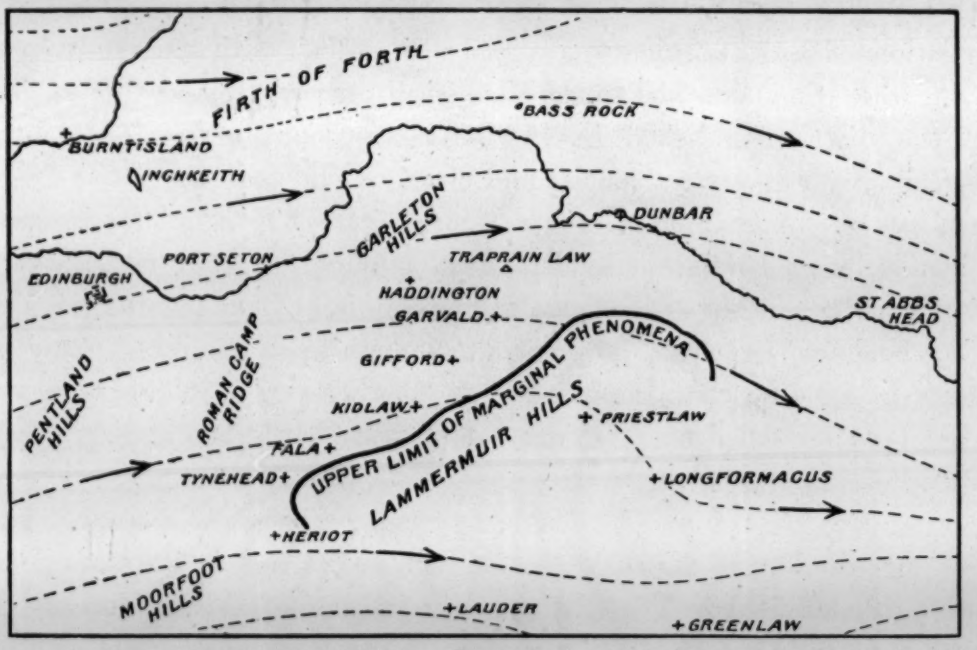



FIG. 1.

self-contained area. His description will appear in the new edition of the East Lothian memoir. Our best thanks are also due to Mr LUNN of the Geological Survey, whose excellent photographs supply the illustrations chosen for this paper. And lastly we would like to record our belief that had it not been for the kindly interest and support continually given to our work by Dr HORNE, it is doubtful whether the paper would ever have been written at all.

## THE MAXIMUM GLACIATION OF EAST LOTHIAN.

The glacial history of East Lothian is one of considerable complication. Our evidence clearly points to a period of maximum glaciation when the hills were completely overridden by a foreign ice sheet; then came a time when the latter began to fail in strength and was unable, even with bulging upper surface, to force a passage for itself, but had rather to accept the high plateau region as an independent centre of

dispersion. Later still the great ice sheet became further enfeebled and shrank away back from the hills, merely leaving small local glaciers to linger on for a while in the deeper recesses of the upland valleys.

No doubt similar complications attended the growth of the great ice sheet, so that one naturally feels some uncertainty in deciding the proper place in the glacial history of the county of any particular event whose record has been preserved. Nevertheless, the tale of the maximum stage of glaciation is not hard to decipher in its broad outlines, and the approximate direction followed by the bottom currents of the great ice sheet will be found indicated on the accompanying sketch map. We would, however, recommend the reader to consult Sir ARCHIBALD GEIKIE's * glaciation map of Scotland,

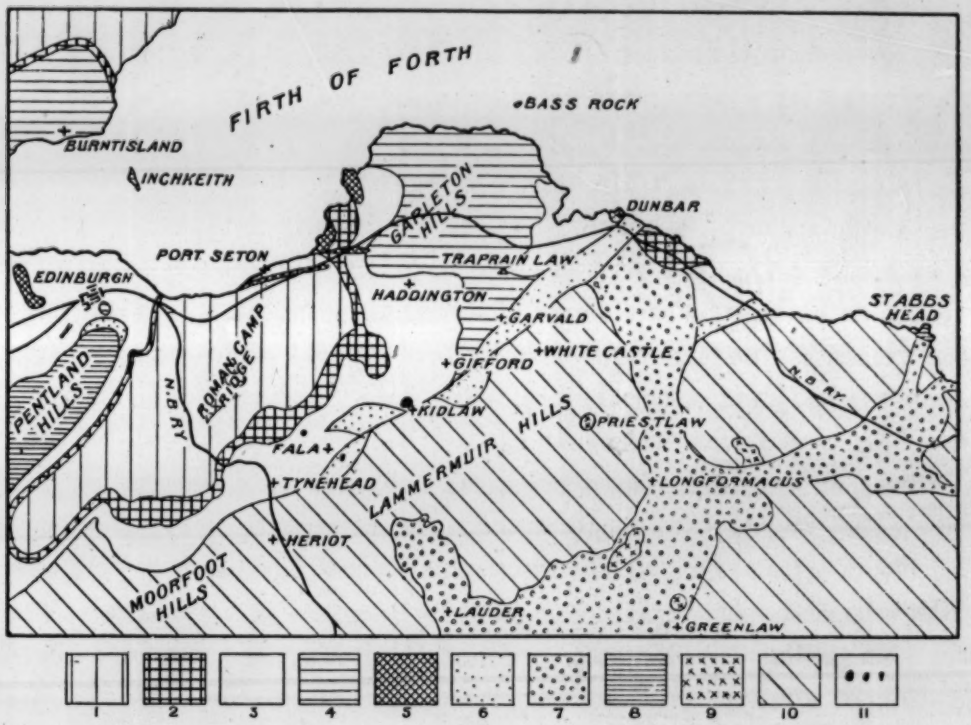



FIG. 2.

1. Coal-bearing divisions.
2. Lower limestone group.
3. Calciferous sandstone series.
4. Carboniferous volcanic rocks.
5. Carboniferous dolerites.
6. Old Red Sandstones.
7. Old Red conglomerates.
8. Old Red andesites, rhyolites, etc.
9. Old Red granites, felsites, etc.
10. Silurian and ordivician.
11. Transported masses of limestone in neighbourhood of Kidlaw and Fala.

since to understand the progress of events in East Lothian he must have a grasp of the main features of the glaciation of the whole central valley. Thus in the west the main ice cap of the Southern Uplands proved sufficiently powerful to ward off invasion from the Highlands, and the two great ice-streams meeting at the base of the southern hills in the plain of Ayrshire turned north-east and south-west to escape either way along the central valley. But the Lammermuirs are low, and are bordered to the east by the plain of the floor of the North Sea, so that before reaching them the Highland stream was able to push its southern companion back upon itself and to creep up obliquely on

* *Scenery of Scotland*, 1901, pl. iv.

to the Silurian Uplands. Once upon the top of the watershed the current turned for a while into a direction markedly south of east; and the same deflection is noticed where the congestion in the basin of the North Sea began to make itself felt upon the great ice stream issuing from the Firth of Forth; for the latter had to pass out in both directions, and thus the current crossing the eastern Lammermuirs bent round into approximate parallelism with the coast towards St Abb's Head. The record of the march of the ice sheet is chiefly preserved in the boulder clay, which it deposited as it went. Our own observations in this connection relate for the most part to the northern front of the Lammermuir Hills and to the district intervening between them and the Firth of Forth. They have enabled us in the first place to confirm Prof. GEIKIE's* record of Highland erratics, since the latter occur throughout the whole area and may be recognised in good numbers even as far to the south-west as Tynehead. Boulders of carboniferous rocks have been carried in company with those from the Highlands far out on the Silurian Uplands, and, according to Dr PEACH, over the other side into the Merse of Berwickshire; while to the north, along the Old Red and Calciferous Sandstone tracts lying at the foot of the hills, the whole country is swathed in boulder clay abounding with limestone, coal, and andesite fragments, all indicating a carry from the west in a direction oblique to the course of the Lammermuirs. East of the outcrop of the Garleton volcanic zone the same tale is told by the appearance of trachytes and basalts among the boulders of the drift; for instance, fragments of the former have been found in boulder clay as far to the south-west as White Castle, where the road leads across the hills from Garvald. Only two more instances need be cited, and these are of special importance, as they serve to indicate in an unusually emphatic manner the direction of the ice flow for the districts which they represent. At Port Seton and along the coast to the east certain conspicuous boulders of conglomerate occur which resemble the Craigmillar conglomerates of the Edinburgh district, and Mr CLOUGH has met with a train of similar erratics along the coast for a mile east of Dunbar. This would indicate an average direction of transport of E. 5° N. across the intervening district. The second example illustrates the deflection of the course of the ice sheet when once it had crossed the watershed. Dr PEACH has traced the carry of the granite boulder derived from the Priestlaw mass, and found that they indicate an ice flow in a south-easterly direction towards Longformacus.

The evidence just considered may usefully be supplemented by reference to the erosion effects produced by the great ice sheet. Striæ have been but poorly preserved, and all records come from the low-lying districts.† They may be tabulated as follows, from west to east;—

Kippie Law (half a mile N. of Traprain Law), E.
Traprain Law (steep south-western face), E. 10° S.

* *Great Ice Age*, 1894, p. 195.

† Striæ in the Garleton Hill area are abundantly preserved, and are well known. Their direction is entirely in accord with that indicated in the sketch map.

Dunbar, E. 5° S. (Mr Muff).
Catcraig Quarry (two miles E. of Dunbar), E. 15° S. (Professor Young).
Shore close to Catcraig, E. and E. 10° N. (Mr Clough).
A striated pavement, Thorntonloch (5 miles S.E. of Dunbar), E. 10° S. (Professor Young).
St Abb's Head, E., 25° S. (Professor Young).

Professor Young* further noticed that the minor inequalities of the low ground have a tendency to run in lines almost parallel with one another, a fact which is well illustrated in a shaded copy of an Ordinance one-inch map (Sheet 33). He attributed this to the result of direct sub-glacial erosion, and noticed that if a line be taken joining Lothian Edge to Tynemouth (see general map), it separates the lowlands into two districts. West of the line the grooving runs E.N.E. or E. by N., but on its seaward side the features "become much more easterly and even a few degrees south of east." This type of ice modelling is not so widely developed in East Lothian as in many parts of Scotland,† but it is well shown in the district south and east of Haddington.

The direction of ice flow indicated by the modelling agrees approximately with that of the few striæ observed, and thus the erosion effects as a whole, where recognisable, serve as a useful check upon the evidence afforded by the deposits. They clearly demonstrate that in the low-lying parts of the county the ice sheet followed roughly the trend of the central valley, until, debouching upon the North Sea plain, it was forced to take a somewhat southerly course, skirting the termination of the Southern Uplands.

The district lying south and east of Haddington affords a good illustration of the special characteristics of an ice-dressed surface upon a large scale. The topography induced is essentially that of a drumlin country. Long low mounds or ridges run parallel with one another, merely separated by shallow broad-bottomed grooves or valleys. If any particular ridge be followed it will presently be observed to sink slowly and gradually until the grooves on either side meet about its termination; others have, however, by this time arisen situated en échelon to their failing companion, and so the group persists though its individual members prove inconstant. The distinction between these mounds and true drumlins depends upon the fact that they have been fashioned in solid rock and are merely coated over with boulder clay, very thin along the crests of the ridges, instead of being entirely formed of the latter. Wherever an isolated resistant mass occurs, this type of sculpture naturally becomes accentuated, and Traprain Law furnishes a familiar example of "crag and tail." By taking note of such where they occur, it becomes evident that the whole grooving must be referred to an ice sheet moving towards the E.N.E. In following this course the current flowed from the area occupied by sedimentary rocks south of Haddington over the igneous rocks occurring south of Traprain Law. The phenomena marking this passage from the soft rocks to

* *The Geology of East Lothian*, 1866, pp. 63, 64.

† Cf. Sir A. Geikie, *Geology of East Berwickshire*, 1863, p. 52, and J. Goodchild, *Glacialists' Magazine*, vol. iv. pt. 1, 1896, p. 1.

the hard are very beautiful. The grooves persist in their original direction, but gradually rise to surmount the obstruction, and upon the other side sink as gradually to their former level. A small patch of alluvium near Morham Church serves to mark the original presence of a shallow tarn excavated along one of these grooves just east of where the change of slope commences.

Certain of the grooves south of Haddington have been employed as temporary watercourses at a later period, but the work of the streams which thus made use of them was chiefly the deposition of alluvium upon the broad bottoms of the hollows.

Elsewhere the sculpturing is not so well developed as in the district just described, but round the termination of the hills it serves to indicate the deflection of the ice current which has already been referred to.

Let us now return from the consideration of the direct effects of sub-glacial erosion to the correlative phenomenon of deposition. The district furnishes three very fine examples of large transported masses of limestone. The most conspicuous is that of Kidlaw, a mass one-third of a mile long and a quarter broad and well exposed in extensive disused quarries. The view that this great mass might really be a boulder was first suggested some years ago in conversation by Mr Howell, and the evidence for this interpretation is threefold.

1. The few exposures in the immediate neighbourhood and general considerations as to the geological structure of the district, point to the conclusion that the limestone is resting on sediments of Upper Old Red or early Calciferous Sandstone age, with associated igneous rocks. The limestone, moreover, has been recognised by Dr Crampton as belonging to the middle and not the bottom of the Lower Limestone group of the Scotch Carboniferous sequence. Under these circumstances one has to account for the apparent absence of a great thickness of strata, all included in a conformable sequence and well developed in the near neighbourhood.

2. The whole mass is in a completely shattered state. Mr Howell* in his original description attributed this feature to the proximity of the Lammermuirs fault. But the longest axis of the "outlier" is directed away from the fault, and it would be very difficult, therefore, to maintain this interpretation; moreover, since Mr Howell mapped the ground, a large basalt quarry has been opened in the immediate vicinity and equally close to the fault. The basalt sill is there entirely unshattered, though the period of its intrusion certainly greatly antedated the faulting.

3. There is a great abundance of limestone blocks, both large and small, in the boulder clay of the adjoining areas, whether it rests upon Silurian, Old Red, or Carboniferous strata.

The second example is recorded by Dr Crampton at Marl Law quarry, a mile N.W. of Fala. It consists of a contorted mass of limestone and marl, lying not very far from the natural outcrop of the group. It may perhaps not be without significance that the Kidlaw and Marl Law masses lie along the same line of glacial transport.

* *Geology of East Lothian*, 1866, p. 55.

The third example occurs at Woodcotte Park, a mile to the east of Fala. The limestone forms two little knolls known as the Little Hill and Meikle Hill respectively. Here, as at Kidlaw, the field evidence strongly suggests that the limestone is resting on the Upper Old Red Sandstone, only in this case upon the south side of the Lammermuir fault. The exposure was known some sixty years ago to CHARLES MACLAREN * and DAVID MILNE HUME,† who regarded it as belonging to a natural outcrop. MACLAREN remarks, however, that he saw none in place. The evidence for believing that these knolls consist of transported limestone is therefore identical with that put forward in respect to the Kidlaw example, and the probability of the interpretation is heightened in that it is not invoked merely to explain a single occurrence. It is noteworthy that Mr HOWELL in his mapping long ago did not treat these smaller masses as being in place, although one of them was formerly quarried and burnt for lime.

The carboniferous limestone seems in certain other places to figure more largely in the drift than might at first be expected; this suggests that in pre-glacial times the more important beds of limestone may have given rise to conspicuous little escarpments with long, exposed dip slopes, and that these furnished an abundant supply of blocks during their degradation by the ice sheet, while at the same time they may have afforded favourable opportunity for the transport of big masses.

## THE RETREAT OF THE ICE SHEET.

We have now examined some of the results of the action of the ice sheet during its maximum development, but perhaps even more interesting still are the circumstances of its retreat. When gradually it was forced to give place to other agents of erosion, it yet was able for a while to impose special conditions upon their operation. Thus step by step the enveloping ice shrank back to leave the Lammermuirs standing like a stone in the midst of melting snows; and stage by stage the memorials of this retreat were furnished by the obstructed drainage of the hill country, joined by the waters issuing from the glacier itself: There are whole suites of channels to bear witness to the former presence of swollen torrents, linking together the long chains of lakes, which then rested in temporary support between the steep ice margin and the slopes of the hill country to the south; and there are also the deposits which accumulated in these lakes and at many an intervening point where the connecting streams had not as yet cut gorges for themselves.

One can even recognise by a careful investigation of the evidence that there were times when the ice sheet renewed its vigour. One can trace its oscillatory re-advances: here it spreads its boulder clay over the floor of a lake where previously sand and silt

* *Sketch of the Geology of Fife and the Lothians*, 1839, p. 74.
† *Coalfields of the Lothians*, 1839, p. 103.

had been collecting, and these re-advancing across the path of a glacial stream it drives the occupant back again into some deserted channel further up the side of the hills.

A point of special interest is the fact that all these effects are restricted below a more or less clearly defined upper limit (see fig. 1). Marginal streams and temporary lakes have scarcely left a trace of their former presence in the higher portions of the hills. Yet it can be demonstrated that this does not mark the upper limit reached by an invading ice sheet, but rather the level at which the retreating ice parted company with its lineal descendants, the little glaciers of its high-level valleys.

Moreover, the district has furnished fresh evidence regarding the relations which locally prevailed between land, ice, and water, when the ice sheet had already withdrawn into the low ground; and, probably what will attract more general interest, it has supplied a number of very beautiful instances of a special type of stream capture, which has greatly influenced the plan of the glacial drainage system. Without entering into detail at present, it is sufficient to say in this connection that there are many cases where a tributary stream has thrown out a cone or delta into a deserted glacial drainage channel and has thus succeeded in establishing a watershed within the latter.*

In order to illustrate the various aspects of the subject alluded to above, we will arrange the evidence under the following heads:—

I. Phenomena illustrating the general conditions which attended the retreat of the great ice sheet.

II. Phenomena illustrating the oscillatory nature of the retreat.

III. The upper limit of these marginal phenomena set by the confluence of the local glaciers with the great ice sheet.

IV. The influence of corroms † and bridge-deltas in modifying the glacial drainage system.

V. Evidence regarding the level of the sea at the time of the retreat of the ice sheet.

## I. Illustrations of the Phenomena Attending the Retreat of the Great Ice Sheet.

East Lothian illustrates extremely well two distinct though cognate aspects of the phenomena which attended the retreat of the great ice sheet. One notices everywhere records of the operation of water under special conditions of restraint; in one place the manifestation may take the form of some monumental piece of erosion, in another of deposit, but everywhere the phenomena point to the action of water, and of water impounded in front of the retreating ice sheet. One of the consequences of this

* Dr Crampton independently arrived at precisely this interpretation in accounting for the partial reversal of the drainage in the Borthwick dry valley, to which further reference will be made in the sequel.

† Corrom (cothrom) is a Gaelic word used in place names in the Ardgour district of Argyllshire, to denote a delta-watershed. Its literal meaning is a "balance," and it is intended to illustrate that a stream issuing upon such a cone has the chance of flowing either the one way or the other.

condition of affairs that has continued to this day is the anomalous drainage system possessed by East Lothian and the adjoining coastal district of Berwickshire, the existence of which has long been recognised. In fact, no better introduction to our whole subject can be desired than the descriptions given, now more than forty years ago, by Sir ARCHIBALD GEIKIE * and Professor J. YOUNG.† Besides giving a general account of the anomalous drainage system, both these authors have singled out for special notice examples which seem abnormal even in the strange company of their fellows, and which, as we shall attempt to show later, owe their special peculiarities to the processes of corrom formation. Sir Archibald's account deals with the Berwickshire area, and runs as follows :—

"Besides the ravines . . . . which are plainly the work of rivulets, there are certain other narrow glens, defiles, or channels (for they vary not a little in size) in which there are either no streams, or runnels so tiny and local that they cannot be imagined capable by their own unassisted operations of hollowing out such marked excavations as those in which they now flow. On the south side of St Helen's Church, for example, there is a deep winding ravine, quite dry, running along the side of the declivity which here descends gently to the edge of the sea cliff. It is open at both its eastern and western extremity, thus running across the neck of a promontory. With the present configuration of the land no stream could ever have flowed along this ravine. Other, but less marked, examples may be seen along the sea front eastwards towards St Abb's Head. Along with these features ought probably to be classed those valleys which go right across the watershed in different parts of this district. Reference has already been made to the valley traversed by the North British Railway ‡ as affording a good illustration." He then proceeds to give a description of the remarkable course followed by Edmonds Dean Burn, which enters the railway pass "within a few yards of the flat watershed," the latter being one of the corroms to which special attention will be directed later; and he concludes his account with the suggestion that some of the peculiarities of this drainage system may be due to the modifying influence of direct glacial erosion.

Professor YOUNG, however, in his description of the East Lothian examples, carefully refrains from any expression of opinion as to the mode of origin of the valleys. Having described the glacial grooving, he proceeds :—"In connection with these glacial hollows fall to be considered certain valleys near the base of the hills, which seem to belong to a system different from that of the present day. The flat green valley § between Deuchrie Dod and Rammer Woods is bounded by steep declivities, covered with low brushwood." After describing this abandoned waterway, the finest in the district, he passes on to the Presmennan Loch channel, a little to the north, and then draws special attention to the peculiarities of the Thurston and Aikengall drainage systems, peculiarities which we now regard as a sequel to corrom formation. Returning

* *The Geology of East Berwickshire*, 1863, pp. 51, 52.
† *The Geology of East Lothian*, 1866, pp. 63, 64.
‡ Between Cockburnspath and Grant's House stations, east of Dunbar.
§ Pl. I. fig. 1.

to the general aspects of the case, he continues: "In all these cases the course of the dry valleys is the same, north-eastwards, and is, therefore, at right angles to the present stream courses. It is difficult to explain their formation by means of the small brooks which flow in their neighbourhood, and their form is not that which would result from glacial erosion. There are many such valleys, some of which are mentioned in the Berwickshire memoir; the same explanation does not, however, remove the difficulties in each case; their solution must, therefore, wait the results of more extended inquiry."

When we add that many of the most typical examples are excavated entirely in drift deposits, it becomes evident that the anomalies referred to cannot be regarded as vestigial inheritances from a pre-glacial drainage system, nor can they be accounted for as the consequence of a selective erosion acting along lines of geological weakness. From what has already been stated the reader will have gathered that we intend to apply the same explanation here as was developed by one of us* in order to account for similar peculiarities in the Cleveland district of Yorkshire.

Sir ARCHIBALD GEIKIE'S remark with reference to the channel on the south side of St Helen's Church might be repeated a score of times. "With the present configuration of the land no stream could ever have flowed along this ravine." In the particular case he cites, it might perhaps be suggested that the valley has been cut back to by recent marine erosion, but such an explanation carries no weight in view of the numerous inland examples. The inadequacy of "the present configuration of the land" is nowhere better illustrated than in certain cases where stream gorges have been cut into the uniform slope of a hill side, following instead of crossing the contour lines. The Pressmennan Loch channel furnishes an imposing example. During the initiation of this gorge it is necessary to suppose that the ice front itself supplied the northern containing wall of the stream, until the latter had sunk its channel into the solid rock.

Almost equally impressive is the entrance to the Chesters Quarry ravine, a mile north of Garvald. It seems at first sight indeed to have been fashioned in sheer contravention to the ordinary laws of Nature, for it originates on an open plane, and straightway leads across the imposing spur of Whitelaw Hill. But once in imagination replace the ice sheet to the north and the difficulty vanishes. A lake forms behind the rocky ridge, and its escaping waters are forced to take the route which at the present time seems so unnatural.

These are merely examples chosen well-nigh at random from a host. The Chesters Quarry defile may also be noticed here as a representative "dry valley"; for not only was it cut entirely by glacially diverted waters, but being so cut it has in later times failed to retain any stream of its own. Naturally, however, a great number of glacial drainage channels are still employed as watercourses; there is in such cases a very marked tendency leading to the formation of corroms and the consequent establishment of short cuts, so that the inadequacy of "the present configuration of the land"

* P. F. KENDALL, "Glacier-lakes in the Cleveland Hills," *Q.J.G.S.*, 1902.

to account for the origin of the anomalous drainage system becomes all the more obvious in that the latter is so conspicuously unstable.

We shall now pass on to the discussion of the modifications other than corrom formation which may be attributed to the streams which at present occupy glacial drainage channels; and as a preliminary step we may allude to a peculiarity of the original glacial channels which has proved itself of great importance in this connection. They have as a rule been cut to a very gentle gradient, and an example occurs, between Kidlaw and Gifford, which one might more fitly describe as the dry valley of a sinuous canal rather than that of a stream. The feature no doubt must be accounted for by the fact that at certain intervals these channels were called upon to conduct away large masses of water which were able to maintain a current even after they had degraded their beds to the local base level. Already several of these valleys have been dammed to form reservoirs or ornamental lakes, and the number is always on the increase; a low dam serves to impound a considerable body of water owing to the extremely gradual fall in the valley bottom; and in fact at Pressmennan* it has been found necessary to place a dam at the head as well as at the foot of the lake. Small natural tarns and marshes are also frequent along the course of the streamless valleys impounded behind screes or deltaic cones.

The glacial drainage channels still occupied by streams can, as a rule, be readily recognised even upon the map, since they form an integral part of the anomalous drainage system of the county. The gorge in which Spott Burn lies, and which proved so terrible an obstacle to the Scots in their attack upon Cromwell, furnishes an excellent illustration within easy walking distance of Dunbar. The burn itself is of very considerable volume, and as it winds along the broad bottom of the valley it may be seen in many places cutting into the steep bluffs on either side. Here at first sight one might reasonably expect to find evidence of well-marked deepening of the channel since glacial times. But the actual phenomena of the case emphatically negative this suggestion, while they enable us to recognise the modification for which the present stream has been responsible. A little to the west of Spott the valley, as we follow it up-stream, bifurcates,† or rather it is joined from the south by another valley of identical type. The remarkable feature is that the direct continuation westwards of the Spott valley is entirely streamless,‡ for the whole volume of water is supplied by the valley entering from the south. Examination of the dry valley proves that it owes its streamless condition entirely to natural causes, and it may confidently be regarded as an overflow channel which has been deserted ever since the final retreat of the ice front from this neighbourhood. It therefore furnishes a datum from which to reckon the greatest possible vertical erosion accomplished by the Spott Burn in post-glacial times. The dry valley enters flush with the bottom of the stream-containing valley, or at most

* The same is being performed for Lammer Loch now that the latter is being extended to form a reservoir.
† Pl. II. fig. 1.
‡ Pl. I. fig. 2.

the difference between the two does not amount to more than four feet, showing clearly that the post-glacial vertical erosion has, in this case, been quite trivial. Standing below the junction of the two confluent valleys we obtain a good view up both, and are able to appreciate at once their similarities and their contrasts. They are both gorges bounded by steep walls; but while the deserted channel has lost some of its original abruptness of outline, owing to the collection of rain wash, it evidently retains a feature which in the case of its neighbour has been more or less completely obscured by the action of the stream. For at every convexity in the course of the dry valley the outer wall is more steeply cut than the inner, showing that the valley was excavated by a stream accurately proportioned to the channel it was cutting for itself,* and of quite a different order of magnitude to the Spott Burn.

The rôle played by the Spott Burn during post-glacial times may now be readily appreciated. Since ever its volume has become so greatly reduced it has wound in small meanders along the valley bottom, cutting now into the one side, now into the other. In this manner it continually supplies itself with as much material as it can transport, and thus as the meanders work gradually down stream, the valley is widened but nowhere materially deepened.

Two or three equally striking examples occur in the neighbourhood of Garvald, but it is important now to point out that some of the East Lothian streams left in occupancy of glacial drainage channels *have* proved themselves capable of accomplishing a notable amount of vertical erosion, and to recognise that in such cases the resultant changes can readily be distinguished. The Braidwood Burn,† a little south of Innerwick, is an excellent case in point. It is a powerful stream, and has cut for itself a pronounced gorge, but the result is far more accurately described as a dissection of the floor of the old valley, rather than a deepening of the same. For the work of the recent stream, with its greatly diminished volume, has been to cut a gorge that winds to and fro along the old bottom, the latter being in large measure still preserved intact.

It is worth while before leaving the subject of these channels to take note of the enormous volume of water which they must at times have been called upon to conduct away. They served to carry off the drainage, not only of the Lammermuirs, but also of the Moorfoots, and in fact of the whole of the Mid Lothian basin, except in so far as leakage was permitted here and there through the fissured margin of the ice sheet. During the earlier stages of retreat this western drainage sometimes found a short cut across the watershed by the pass between the Moorfoots and Lammermuirs, which has been taken advantage of in our own days for the railway leading south to Galashiels. But the summit level here is 884 feet, so that for a long period this short cut was not available, and the Mid Lothian drainage had perforce to pass right across East Lothian and part of Berwickshire to reach the sea. Several routes were successively employed

* This is a general feature of dry valleys. See *Glacier Lakes in the Cleveland Hills*, p. 483. The type example for East Lothian is furnished by the Danskine Loch channel, two miles east of Gifford.

† Pl. II. fig. 2.

by the waters passing from the one natural drainage area to the other, and one of them is of such importance as to deserve special notice. It is the Borthwick dry valley, connecting the course of the Gore and Tyne waters, and crossed by the railway just south of Tynehead station. The changes which have led to its abandonment will be dealt with in a later section, so that we shall only notice here the advantages which it owed long ago to its particular situation. The Mid Lothian and East Lothian basins are separated by a line of undulating hills, constituting the Roman camp ridge which extends northwards approximately at right angles to the general trend of the margin of the retreating ice sheet. The col at the southern extremity of the ridge is not well marked, but once the Borthwick channel had been established at this ill-defined pass and had been excavated to its present depth, the ice sheet had to retreat fully $2\frac{3}{4}$ miles further to the north before disclosing any opening of lower altitude across the ridge. The Borthwick channel was therefore employed for a protracted period during the retreat, and at one time must have served to drain an important lake occupying a portion of the Mid Lothian basin.

We may now pass on for a while to consider briefly the deposits which were produced by the agency of the same constrained waters as cut out the drainage channels just described.

Great masses of sand and gravel encompass the Lammermuir Hills round about, and have long been familiar to Scots geologists. Like other accumulations of their kind, they appeared to the earlier workers as the memorials of great submergences. Professor Young,* however, in his record of the distribution of the deposits, refrains from offering any suggestion as to their mode of origin; and later, Professor Geikie,† in several brief references, rightly regards them as of fluvio-glacial origin.

The glacial age of the gravels is beyond question. They overlie and here and there intercalate with the boulder clay. They everywhere contain erratic pebbles, most conspicuous among which are fragments of coal assorted into special layers in accordance with their low specific gravity, and finally their distribution makes it necessary to believe that they formed in proximity to the retreating front of the ice sheet.

Various factors have been concerned in their production, and we may mention the following main sources from which they have derived their material.

1. The hill country, owing to the melting of its local glaciers, the re-opening of its normal lines of drainage, and the rapid waste of the boulder clay covering its steeper slopes, supplied a very large proportion of the whole. Along the northern front of the hills the contrast between the composition of the gravels and that of the boulder clay is rendered very marked by this circumstance. The boulder clay resulted, as we have seen, during a passage of the ice sheet from west to east, often from low ground to high, while the gravels of this series travelled in large measure from south to north, and always from high ground to low. Thus while the boulder clay, carried on to the Silurian Uplands, is charged with the débris of the rocks of the central valley, the

* *Geology of East Lothian*, 1866, p. 65.

† *Great Ice Age*, 1894, p. 211.

gravels, on the other hand, which extend on to the latter from the hills, are everywhere characterised by pebbles of Silurian grauwacke.*

2. The excavation of the glacial drainage channels is responsible for another great part of the material, especially, perhaps, that which litters the coastal plain.

3. The ice sheet itself also no doubt directly supplied some proportion of the deposit.

As to the conditions regulating the accumulation of these sands and gravels, it seems certain that for the most part they formed either as the deposits of temporary ice-dammed lakes or as gravel spreads extending between the ice and the hills and reaching, along the coastal region, far out over the shelving bottom of the sea.

It is difficult now to distinguish between these somewhat differently accumulated deposits, and, in fact, one can only speak with confidence in special cases. It has been found impossible to draw a line separating the gravel spread of the coastal plain into two portions, according as it formed above or below the ancient high-water mark, or in the inland sections to differentiate the material which accumulated in the temporary lakes of the period.

Not only were the original boundaries in the majority of such cases very blurred and ill-defined in their nature, but also the deposits have since frequently taken on outlines corresponding to a mature stage in erosion. We may illustrate this fact by an example from the neighbourhood of Upper Keith,† north-west of Fala. Several interesting sections occur here, which render this the type area for the study of the deposits, but their full description will be delayed till the section dealing with the oscillatory nature of the retreat of the ice sheet. For the present it suffices that the sections show a great mass of evenly bedded sands, with here and there a layer of gravel or another of laminated clay or warp. The whole appears as the deposit laid down in the tranquil waters of a great lake, but now so deeply eroded that it has taken on the moundy form which one naturally associates with a sand district. Here and there, indeed, flat stretches do exist which at first sight might be taken to mark an old level of the lake waters; but, as will appear later, these merely indicate the outcrop of a more resistant bed of boulder clay which lies intercalated in the sands, and have therefore an entirely different significance.

With this example in view it would be rash indeed to regard any of the "kame" outlines, which are locally developed, as due to the preservation of original forms of deposit. In fact, the most conspicuous example of kamiform ridges of gravel in this district are afforded near Woodhall, south of Spott, where a section shows that the even and almost horizontal bedding of the deposit bears no relation whatever to the external form of the mounds, but is sharply truncated by the steep hill face. The interpretation is obvious in this particular instance,‡ for the ridges are part of a gravel-spread which formed between the hills and the ice sheet at a time when the glacial waters were being

* Numerous exposures in the neighbourhood of Upper Keith, for instance, illustrate this point.

† Pl. IV. figs. 1 and 2.

‡ We do not suggest for an instant that true kames of deposit do not exist in other districts.

supplied with such a superabundance of material from west and south that even they were unable to cope with it. Later, when this supply had become in part exhausted, and the passes to the east had at the same time been deepened, the gravel-spread was attacked and kamiform ridges produced. In fact, the latter are here nothing more than the remnants left between successive glacial drainage channels. The disposition of the channels in this case is such as to indicate that they were formed when a re-advance of the ice sheet had carried it forward again over the gravels; but there are equally numerous cases where a wide stretch of sand and gravel has been dissected by glacial drainage channels, for which such an interpretation is quite unnecessary. In imagination place an ice sheet abutting against the front of any hilly tract of country, and suppose that it remain stationary for a long time in the same position. The governing principle operative throughout will be the tendency of the obstructed drainage to furnish itself with a suitably graded channel leading to the nearest available outlet. Hollows and gentle slopes will be loaded with sands and gravels, while ridges, which rise above the general level, will be breached by cross-cut channels: but, supposing the process perfectly continuous, reach after reach, where at first sediments had accumulated, would attain, as it were, its saturation point and, refusing further deposit, would henceforth enter upon a career of erosion.

Under more natural circumstances further complications would be certain to arise: thus we have already hinted several times at the oscillations which marked the withdrawal of the ice sheet from the Lammermuirs; it is possible, however, in a first broad view, to neglect the results attributable to these oscillations, since they affect matters of detail and not of general principle. But even then the account we have sketched above is inadequate, since the opportunities for the destruction of sand and gravel deposits formed in front of a stationary ice sheet are evidently far less numerous than if the ice sheet were slowly and continuously retreating; thus many a time a once continuous terrace must have become reduced to a mere collection of isolated remnants.

We are now in a position to read the evidence afforded by the East Lothian sands and gravels. A remarkable feature in their distribution is that they are for the most part concentrated into two definite and quite distinct areas in which, as we shall endeavour to show, they have accumulated under somewhat different conditions. The first of these areas is a well-marked belt or zone of maximum accumulation extending from Tynehead in the west right round the hills to Oldhamstocks in the east, while the second includes what may be termed the coastal spread.

Examination shows that the first of these two zones or belts is roughly contained within limits set by the 700- and 500-foot contour lines respectively; further, a study of the mode of occurrence of these deposits in the field shows that many of the gaps which break the continuity of the belt are certainly the result of erosion. In fact, it seems tolerably clear that at one time a sand and gravel terrace, similar to that described by Prof. Geikie* for the Strathavon Hills, near Glasgow, reached round about the

* *Loc. cit.*, p. 175, pl. iii.

northern and eastern flanks of the Lammermuirs, passing by Tynehead in the west and Oldhamstocks in the east. Between these two villages the continuity of the terrace was broken by two important spurs, namely, Deuchrie Dod and Cocklaw Hill. Behind each of these at one time or another important lakes were doubtless imprisoned, and it seems probable, from the nature of the deposits in the Upper Keith district, that Deuchrie Dod served temporarily as the eastern limit of a narrow marginal lake fully fourteen miles in length. But the history of this terrace was long and varied; we shall presently have to deal with evidences to show that the ice in front of which it formed was frequently oscillating to and fro. In fact, it marks much the most important halt, if such a name may be applied to a limited though restless wandering to and fro, which occurred during the retreat of the ice sheet from East Lothian. Thus it came about that the marginal drainage system of this zone reached a mature development along the lines indicated above. At first almost the whole extent of the marginal area was loaded with sediment, though, of course, the supply varied greatly in amount and from place to place; erosion occurred only across the two spurs already mentioned until the general lowering of the base level caused the emergence of minor ridges and the other consequences which we have indicated above. But before the ice sheet had finally retired, the terrace so formed had been dissected from end to end by marginal streams and the work of its demolition had already far advanced.

Above and below the limits of this great terrace we may recognise others, but never on the same grand scale. A well-marked higher terrace may be referred to leading eastwards from White Castle towards Deuchrie Dod. Its level is approximately 800 feet above the sea.

We shall now consider the other great zone of deposit, that of the coastal spread. At Oldhamstocks it comes into contact with the great Lammermuir terrace, but it is obvious in the field that the deposits of this locality have an extremely complex history, and that those occurring at high levels were formed at a time when the ice sheet must have blocked all direct egress to the sea. The whole coastal spread is, in fact, built up on this plan, and it owes its continuity to the juxtaposition and overlap of deposits formed successively and not contemporaneously. It cannot therefore be regarded as an entity, even in the same extended sense in which that term might be used to describe the complex Lammermuir terrace. It is merely the gravel spread which formed where the mouths of the glacial drainage channels debouched upon the coastal plain, and as these came into being in succession from south-east to north-west, following the retreat of the ice sheet, it is obvious that the coastal gravels near Oldhamstocks, for instance, were formed at a considerably earlier date than those about the mouth of the Tyne.

## II. Phenomena Illustrating the Oscillatory Nature of the Retreat.

We have already referred to the great accumulations of fine sands, silts, and gravels which occur in the Upper Keith neighbourhood. They have all the appearance of having been laid down in a great lake, and it seems necessary to suppose that during the time of their formation the ice sheet of the lowlands lay in close proximity to the north and thus served to dam back the waters in which they accumulated. A closer inspection of the many good sections * occurring in this district confirms this interpretation, since such an examination affords independent and clear evidence of the continued proximity of the ice sheet during the formation of the sands.

Two of the sections, both of them occurring along the course of the Keith water, are specially clear; the first of them constitutes the Red Scar,† a little north of Costerton cottage, and the second ‡ lies just to the west of the road from Upper Keith to Ormiston. Their details are as follow:

| | Feet. | | Feet. |
|---|---|---|---|
| 4. Sand . . . | 53 | Not exposed in this section. | |
| 3. Boulder clay . . | 13 | Boulder clay (top not seen) . | 6 |
| 2. Sand . . . | 15 | Sand . . . . . | 65 |
| 1. Boulder clay (base not seen) . . . | 37 | Boulder clay (base not seen) | 33 |

Even in the Red Scar the section is incomplete, and the upper sands must be fully 150 feet in thickness. The thin gravel beds sparingly interbedded with the sands carry a conspicuous proportion of grauwacke pebbles derived from the Silurian Hills two miles to the south, but the larger blocks of the intercalated boulder clay consist of sandstone, etc., so that it seems necessary to suppose that the latter was deposited by the lowland ice sheet. In fact, we take its presence to indicate that this glacier was not melting away as an inert mass of ice, but that it was ready, when climatic conditions favoured, to re-advance on to the floor of the temporary lake which spread out before it, and there deposit a covering of boulder clay upon the sands and silts which had previously been collecting. The intercalated boulder clay can be traced with almost complete certainty for a distance of a mile in a direction parallel with the ice margin, and a quarter of a mile at right angles to the same, without any indication of coming to an original limit, so that the oscillation recorded here seems to have been of considerable magnitude. The positions of the best sections in this interesting district are indicated by asterisks placed on the general map.

Many other exposures occur along the Lammermuirs which tell the same tale as those of Upper Keith, but not in so impressive a manner; we need therefore only allude here to the readily accessible exposures in the railway cutting soutl of Tynehead

* The interstratification of sands and boulder clays here was first noticed by Mr Anderson.
† Pl. IV. fig. 2.
‡ Pl. IV. fig. 1.

station, before passing on to indicate other lines of evidence which point equally clearly to the oscillations in which the great ice sheet effected its retreat.

In the first place, still dealing, as at Upper Keith, with the deposits of the great Lammermuir terrace, we may draw attention to the highly significant erosion forms which they locally present. As already noticed at Woodhall, south of Spott, the terrace has been so completely dissected by a series of glacially directed stream courses that its sands and gravels have now assumed a kamiform aspect, and it is obvious in the field that the ice sheet which directed this erosion must have re-advanced after a retreat, until it actually came to stand upon the top of the spread of deposits which previously had accumulated before it.

But this is not the only way, or indeed the most important way, in which oscillations of a retreating ice sheet may be recorded in the erosion effects which it determines, and to make our line of argument more readily appreciated, we have inserted the following explanatory diagram.

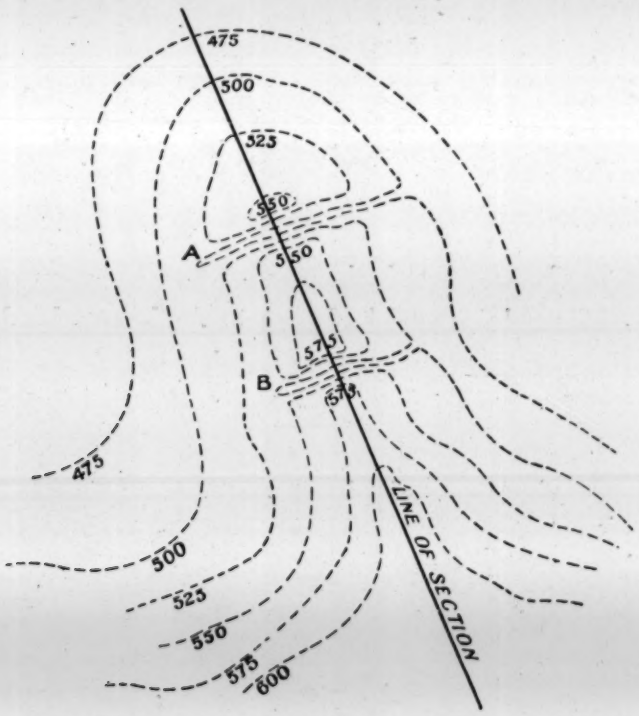



FIG. 3.

The contour map and section in fig. 3 show an ideal case of a spur reaching out from a line of hilly country at right angles to the general trend of an ice margin retreating towards the north. The ridge has been breached by two overflow channels,

the one at A, the other at B. It will also be observed that the top of the A channel lies at a higher level than the bottom of the B channel, so that the latter cannot have been excavated to its present depth when the former began to be cut. This indicates that the two were not employed merely during a continuous retreat of the ice front, for under such circumstances no channel could have begun to cut north of B until the ice sheet had withdrawn beyond the 525-foot contour. It is evident, then, that these two were cut, in part at least, during an advance of the ice sheet, so that if there is reason to believe, from the state of their preservation, that they belong to the period of retreat of the ice sheet at all, and not to the period of its growth, we are forced to conclude that the advance which they indicate must have been of the nature of an oscillation affecting the general retreat.

In applying this line of argument it is necessary, in the first place, to compare only valleys that are dry, so as to eliminate uncertainties due to post-glacial erosion. It will be noticed that we here compare the top of A and the bottom of B. Post-glacial change can only be supposed to act so as to lower the former, and, in the case of a dry valley, to raise the latter so that if the top of A be still higher than the bottom of B we may confidently believe that the difference was no less marked in glacial times.

The oscillations of the East Lothian ice sheet have left several memorials of the type described above. Black Law, a little to the west of the kamiform gravels of Woodhall, furnishes an excellent example, for instance; so also does the great Rammer Cleugh channel behind Deuchrie Dod,* described by Professor YOUNG, but in the last-named case there is additional evidence showing that oscillations at this stage were repeated more than once. In the first place, a high-level channel, as shown on the general map, obviously furnished the original eastern continuation of this overflow channel, and must have been blocked by a re-advance of the ice before the eastern portion of the present course came to be employed. Then began the excavation of the magnificent gorge which is known as Rammer Cleugh. It is two hundred feet deep and cut through solid rock, the finest example of a dry valley in the county. It is hardly conceivable that the great ice sheet retreated regularly and slowly during the cutting of this deep channel, since under such circumstances it only had a mile in all to travel before presenting the marginal drainage with a fresh path, for escape, lying to the north of the Dod. We cannot, however, point to any direct evidence indicating oscillations at this stage; but later, when the cleugh had been excavated to its present depth, a re-advance is clearly indicated by a group of morainic mounds charged with great blocks of red sandstone carried from the lowlands, which rest actually on the bottom of the valley near its western extremity. It is interesting to note that while this line of moraines was breached by a continuance of the drainage in an easterly direction, the small stream which now occupies the gap flows in the reverse direction as a result of subsequent corrom formation.

The same kind of evidence is rendered available owing to records of underground

* Pl. I. fig. 1.

operations in the neighbourhood of Ormiston, of which Dr CRAMPTON has kindly given us the following interesting account. "To the west of Ormiston, the light railway follows what has at one time been an important line of drainage. It is shown by bores to be in large measure choked by alternating deposits of sands and gravels, and it is occasionally so completely filled up that its edges no longer make a feature at the surface. Another channel lying to the south and east of Ormiston, and passing close by Pencaitland, has also been proved to contain a considerable depth of clay and sand, and from some of the bore records it can be definitely recognised that boulder clay here occurs superimposed upon sand and mud. The journal of one of these reads as follows :—

Surface, 1 foot.
Clay and stones, 17 feet.
Sand and gravel, 13 feet 10 inches.

The hollow, despite its partial infilling, is still strongly marked and appears to have been reopened to some extent by the flow of water at the time of the retreat of the ice sheet which had deposited the boulder clay mentioned above. The explanation which seems most applicable to these two channels is that they were marginal stream courses formed in front of the ice sheet during its oscillatory retreat, and therefore liable at times to be overwhelmed by a temporary re-advance of the glacier and in this manner choked with boulder clay."

### III. THE UPPER LIMIT OF MARGINAL PHENOMENA SET BY LOCAL GLACIATION.

We have, up to the present, been dealing with the phenomena which marked the retreat of the great ice sheet from about the 1000-foot level downwards. Above this the processes at work were evidently somewhat different, for they have left a record of their operations which, though meagre, is still eloquent of the special conditions prevailing during the earlier phases of the retreat. As soon as the Lowland ice had no longer power to surmount the Lammermuirs, the dissected plateau in which this range culminates became for the time being an independent area of dispersal, though still retained within the confines of the great ice sheet. Even when the latter had shrunk back for some little distance from the summits of the hills, every hollow and valley was choked with névé, and many a one nourished its own little glacier, so that every here and there a tongue of ice still reached down the gentler slopes to join its great companion in the lower ground.* So long as this last condition held, it is obvious that marginal drainage on a large scale must have been impossible, and we have at once the explanation of the upper limit referred to above. Later, however, a stage arrived when the Lowland ice parted company with the local glaciers, for while the former continued

* It must not be overlooked that the evidence adduced in this and the preceding section has a most important and direct bearing upon the climatic conditions of the period.

its retreat from the hill country, the latter shrank back into further recesses of the high-level valleys and finally dwindled away to nothing.

Very simple and straightforward evidence of local glaciation is afforded in the neighbourhood of both Lammer Law and Soutra Hill. The former case is illustrated in fig. 4. The Sting Bank Burn follows a deeply trenched valley running eastwards from Lammer Law. A neatly cut high-level channel leads right across the ridge bounding the valley on its northern side. It shows all the characteristics of a winding stream course, with steep banks facing every curve. Its elevation above the Sting Bank Burn is about 200 feet; it is now quite dry, and as it cuts right through the ridge it has no catchment area at its head whatever. It follows the bottom of a faintly marked transverse col, which is lower than any other point for some distance along the ridge to the east. To explain this high-level channel we must admit that the course of the Sting Bank Burn was choked with ice streaming in from the tributaries to the south, but that a small lake was permitted to form in the north-eastern angle of the valley which drained across the col at its lowest point, and thus led to the cutting of a stream course in what one would now style an impossible position. As the water which cut this channel drained outwards from the hill country we have clear indication that local glaciers remained in the high valleys after the great ice sheet had shrunk to a lower level. We need only notice that the configuration of the land emphatically negatives any suspicion that the great ice sheet could block the mouth of the Sting Bank Burn or the Hopes Water into which the latter flows, so as to form a lake whose outflow might have caused this channel, for under such circumstances there could have been no possible escape for a stream across the col, which would itself have been submerged.

An exactly similar deserted high-level channel leading outwards from the hill country is shown on the general map just west of Soutra Hill (see general map); and while it confirms the deductions we have already drawn, it also enables us to appreciate an interesting case of stream diversion which has occurred upon the other side of the same hill. Originally, or rather in pre-glacial times, the Armet Water had its source at Nine Cairn Edge, for the valley still continues naturally in that direction, but the upper portion of the stream has now been diverted to the north and has given rise to the Linn Dean Water. It seems clear on the ground that the local glacier, which occupied the whole of the Armet valley, protruded a tongue northwards to the east of Soutra Hill. The high-level gravels on either side of the Linn Dean Water represent in a sense the morainic deposits of this tongue of ice, while the gorge of the stream was cut by the waters issuing from the same. Certain minor diversions of the stream, moreover, suggest that the glacier sometimes extended forward even into the water-worn channel of the burn and forced it to cut a new course for itself a little to the one side or the other.

It is not impossible that the diversion of the Blinkbonny Burn (north of Sting Bank Burn) should also be ascribed to a precisely similar interference on the part of a local glacier. Originally this stream joined the Harelaw Burn to the east. Such examples

illustrate the final stages which may be reached in a development originating in so small a thing as the high-level channel leading across the col out of the Sting Bank valley.

In the cases so far considered there is no direct evidence * that the local glaciers of the higher valleys came into being during the retreat of the main ice sheet. The excellent preservation of the stream channels described proves indeed that they were produced at a later date than the final overwhelming of the hills by foreign ice, while the oscillatory nature of the withdrawal of the latter itself suggests that climatic conditions were favourable, at the time of the retreat, for a temporary retention of small glaciers in the valleys of the hill country. Fortunately, however, this important point

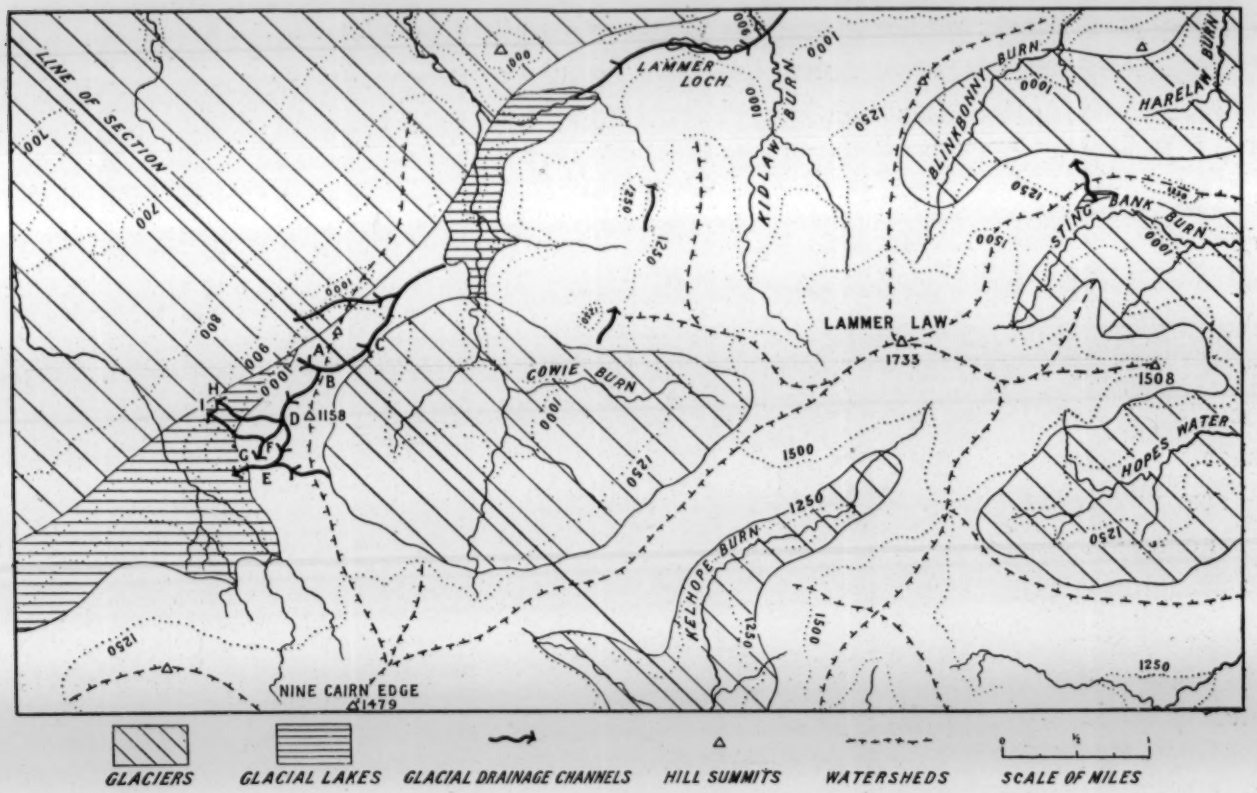



FIG. 4.

can be settled definitely by a consideration of the complicated series of events recorded in connection with the local glacier of the Cowie Burn valley (figs. 4 and 4A).

The critical sections occur along the ridge which runs northwards from Nine Cairn Edge and forms the western boundary of the Cowie Burn valley. Attention will be restricted to the system of channels lettered in the text map. Of these only the example marked A B C is significant in regard to the question of local glaciation, but it would be unsatisfactory to attempt to deal with it without explaining the origin of the others.

The first thing that strikes the observer in visiting this ridge is that the channels of this system have delivered water (they are all now perfectly dry) both in an easterly and

* We prefer, for the present, not to regard the absence of the ordinary marginal phenomena from the region of local glaciation as direct evidence on this question, to avoid reasoning in a circle.

in a westerly direction. The phenomena are well marked and quite unmistakable. To understand this interesting complication one must recognise that the system of channels lies wholly above the 900-feet contour; that is, above the summit level (884 feet) of the Heriot railway pass, six miles to the west. An examination of this pass shows that it was actually employed as a glacial drainage channel by waters travelling from north to south across the hills. As a matter of fact the pass was sometimes used in the reverse direction also, but when available for the northern drainage, it of course offered an opportunity of escape for waters empounded in front of the retreating ice sheet for some distance to the east of its entrance as well as to the west.

Now a glance at the general map will show the even course followed by the 1000-feet and 900-feet contours between the mouth of the Heriot Pass and the northern slopes of Lammer Law, and it will be readily understood that very slight differential movements of the ice front might lead to flow of water in the one direction or the other across the ridge we are at present considering.

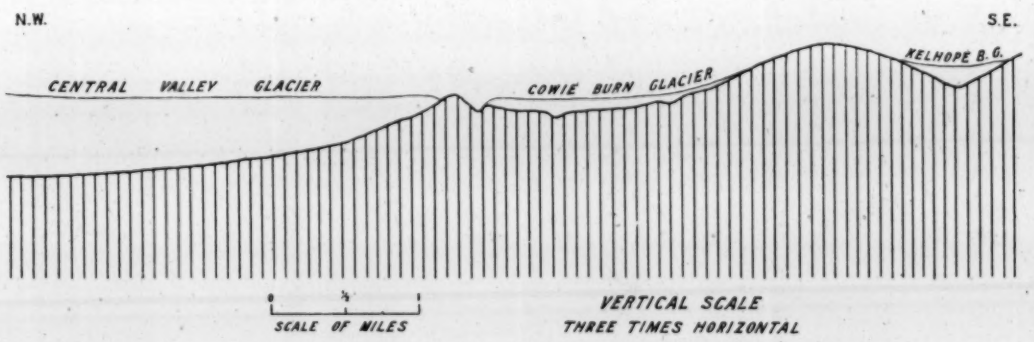



FIG. 4A.

Having discussed this point, the next question is as to whether the channel A B C, draining east, was cut earlier or later than the channel B D which drains west by various mouths. The answer is attained by a line of argument already developed in a previous section. The top of the channel cut at A is higher than any point in the bottom of the channel B D draining west from B, therefore it would seem that A was cut before B D. The water entering * at the intake A flowed across the low col in the water shed at B, and then, instead of following the uniform slope of the hillside *down* into the Cowie Burn, was deflected so as to run *along* the side of the ridge, cutting a channel B C, forty feet deep, in this position. One can scarcely avoid the conclusion that this channel started in a gutter of which the south-eastern wall was the front of a small glacier occupying the Cowie Burn valley. Once, of course, the stream had lowered its bed into the rock of the hill side it would become self-supporting and could dispense with aid from the local glacier. All the time, however, the great ice sheet must have remained to impound the lake that discharged through A. We are justified, then, in picturing a time when these two glaciers, the large and the small, faced one another across the

* This is the condition of affairs shown in fig. 4, although the other channels of the district are also shown.

narrow ridge, and the contemporaneity of the local and foreign glaciation of the district can scarcely be doubted.

The next stage in the history, so far as it can be unravelled, was marked by an advance of the great ice sheet blocking the intake A, and also the escape by way of the Lammer Loch channel to the east. At the same time the Heriot pass, far to the west, happened to be available, so that drainage took place along the ice front cutting the channel B D E. A partial retreat allowed the water to follow another course B D G, and further retreat allowed of lateral escape simultaneously from two points along this channel leading to the excavation of the cross contour courses D H and F I. That these two did come simultaneously into operation is almost certain from the fact that the bottom of the lateral channel leading out at D is slightly deeper than the high-level entrance to F G, so that had D H been formed first, F I could not have been reached by water, and therefore could not have been excavated at all. On the other hand, it is impossible to imagine F I cut first, for its exit could not have been closed again by the ice sheet without also closing that of D H. Further, there is direct evidence in the field that the original depressions at D and F, before either was breached, must have been at approximately the bottom level of the groove B F G. Once these lateral escapes were opened and cascades had formed on the steep hill slopes, the channels were rapidly deepened. F I seems to have offered a freer escape at first, for it evidently carried the greater bulk of water.

We did not make a particular study of the deposits of the local glaciers of the Lammermuirs. No doubt they supplied a considerable proportion of the material of the great Lammermuir terraces of sand and gravel, but we consider that the chief memorial of their existence is the protection which they provided to the upper part of the range from the ravages of marginal stream action. At the same time the following description by Sir ARCHIBALD GEIKIE* seems to indicate that the local glaciation may have been responsible for the production of a certain amount of morainic material. We quote in full: "Between the heath and the rock there intervenes, on the higher parts of the Lammermuir range, a mass of rudely stratified rubbish, to which, in the progress of the survey, the provisional name of Surface Wash has been given till its true history is better understood. It lies along the ridge between the head of the Hopes Water and the Kilpallet Heights. It is usually a sandy clay or earth more or less distinctly stratified, and containing pieces of greywacke and shale, often well striated. Though frequently different in character from the rocks immediately adjacent, these stones cannot have come from any great distance. The deposit is only a few feet in thickness. Perhaps it is to be regarded as the remanié of the boulder clay, washed down and reassorted by rain, though the comparatively small number of the striated stones and the irregularity of the striation have sometimes suggested that this accumulation may be as old as the snowfields of the glacial period."

* *Geology of East Lothian*, 1866, p. 65.

## IV. The Influence of Corroms and Bridge Deltas in Modifying the Glacial Drainage System.

We have already seen that the glacial drainage channels of East Lothian have characteristically a very gentle gradient. This feature owes its origin to the magnitude of the torrents which the channels were called upon to cope with during the intermittent floods of summer-time. Now it frequently came to pass that a low-grade valley of this type was established at one stage in the withdrawal of the ice sheet, to be left later on, as the retreat continued, open at its head and deprived of its main supply of water. Some little trickling stream might still perhaps wind its way along the bottom, but such would obviously prove quite incapable of coping with the tributes of sand, gravel and alluvium delivered by burns descending into the gorge on either hand. Deltaic cones have been formed at the entrance of every side stream.* They are sufficiently conspicuous to be easily recognisable, and resemble exactly well known instances in other localities.† In the upland districts they furnish sites for the shepherds' cottages, and include the only patches of land brought under cultivation. They not infrequently obstruct the insignificant drainage of the main valley, and so give rise to small tarns and marshy tracts situated in their rear.

By way of illustration the number of cones which have been formed along the course of Edmonds Dean was determined (see general map and fig. 5), and attention was paid to the path traced out by each tributary stream in flowing down its delta. Thirteen cones occur in a distance of two miles, and of these, six drain centrally, two down stream and five up. The drainage directions here given refer only to what occurs on the actual surface of the cones, for on reaching the bottom of the main valley all the tributaries turn to flow south-east—the original direction followed by the glacial drainage. The cone occurring furthest up stream has, however, very nearly raised itself to the entrance level of the pass, and an inconsiderable addition to its height would develop it into a corrom or delta watershed.

The number of fully-formed and operative corroms modifying the glacial drainage plan of the county is so great that an enumeration is impossible. To realise the important rôle which some of these corroms play, one has only to seek out the great highways which were established, under conditions of glacial restraint, to connect up drainage areas previously distinct. In almost every case the striking feature here is the very minor importance of the re-distribution of drainage permanently effected; the lines of communication temporarily employed are now blocked by the formation of corroms which coincide roughly in position with the old pre-glacial watersheds. Further, the slight interchange involved in this process has taken place, more often than otherwise, in a direction contrary to that of the old glacial stream. The cause of this

* Pl. III. fig. 1.

† J. E. Marr, *Scientific Study of Scenery*, second edition, p. 166 and pl. I. C. Russel, *River Development*, p. 138.

is not far to seek. Suppose that a natural drainage basin A is forced by glacial obstruction to seek an outlet through a neighbouring basin B, and that a level-bottomed gorge is thus established connecting the two. On further retreat of the ice sheet a readier way of escape will likely present itself to the waters of the A basin, while those of the B basin may still persist along the same route to the sea as heretofore. Under these circumstances it would be natural for a tributary of the B system to establish the corrom blocking the highway, since thus it would share in the advantages obtained by the A drainage.

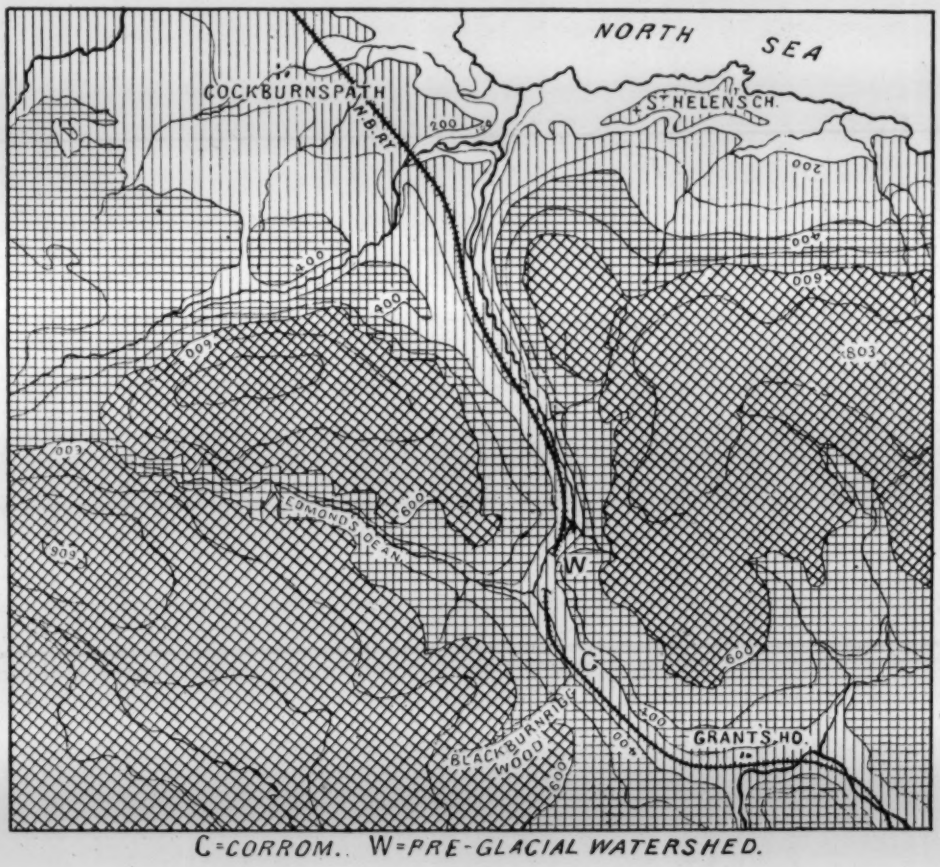
Four very notable illustrations are afforded in our district of the action of the processes which we have outlined above. Thus there is the striking instance of the railway pass between Cockburnspath * and Grant's House, which it will be remembered was specially noticed by Sir ARCHIBALD GEIKIE in his description; then, again, there are the two great highways, in part occupied by the Aikengall and Thurston Burns respectively, to which Professor YOUNG directed attention, and which serve to isolate in the one case Cocklaw Hill and in the other case Spott Hill from the main mass of the Lammermuirs. Last of all, far away to the west there is the Borthwick channel, which for so long a time connected the Mid Lothian and East Lothian drainage areas; as mentioned before, Dr CRAMPTON, working independently, has come to the same conclusion as ourselves with regard to the changes that have brought about the desertion of this last-named channel, and his account will shortly appear in the second edition of the Geological Survey Memoir dealing with the Edinburgh district.

Let us now take the first of our four principal examples, that of the railway pass between Cockburnspath and Grant's House (fig. 5). The position of the pre-glacial watershed, which formerly broke the continuity of this valley, can readily be recognised just at the point where the railway passes through a short tunnel to avoid taking an awkward little bend to the west. On the two sides of this old watershed the valley has passed through somewhat different stages of development. South of the col the glacial waters, for long supplied by the channel of Edmonds Dean, had nothing to do but deepen the old valley which served to conduct them towards the sea;† but to the north of the col they had to deposit layer upon layer of gravel, sand, and silt, and thus choke the lake which formed in this position, while, when crossing the col itself, the waters were always busy cutting and digging. So it came to pass that depositing in one place and excavating in another, they never rested until they had graded the whole to one uniform gentle slope inclining from north-west to south-east. But now the ice retired and allowed the marginal drainage to escape round the north of the obstructing ridge by the St Helen's Church channel, described by Sir ARCHIBALD GEIKIE, and the great highway was abandoned which had cost so much labour to establish. The corrom

* Pronounced Copperspeth.

† A triangular mound near the southern exit of the tunnel is artificial, being composed of angular rock débris, with occasional brick fragments, top-dressed with sand and boulder clay to allow of planting.

now dividing the valley into two is a fairly conspicuous mound* built out by a little stream entering from Blackburnrig Wood; it lies half a mile to the south-east of the pre-glacial watershed, and serves well to illustrate the general rule that a drainage area which has received water from a neighbour under conditions of glacial restraint has often to pay back with some of its own when that restraint is removed. The explanation given above clearly applies here, for the streams which continue along the route previously taken by the glacial torrent have not succeeded in deepening their course, while the Edmonds Dean Burn, which enters north of the corrom, but still south of the




C=CORROM. W=PRE-GLACIAL WATERSHED.

FIG. 5.

pre-glacial watershed, has found a comparatively rapid drop by following the reverse direction, and has thus been enabled to cut a gorge for itself through the old lake deposits, which is fully a hundred feet in depth. A very conservative estimate of the advantage gained can be arrived at by a consideration of the following figures: the height of the corrom above sea-level is 396 feet, and this fall can be achieved in the one direction in three miles, as contrasted with twelve miles in the other.

Turning next to the highway which leads round behind Cocklaw Hill (fig. 6), we find a similar instance of the removal of a pre-glacial watershed and the later formation of a corrom further to the south. It is the Aikengall Burn which, entering the great through valley about a quarter of a mile beyond the site of the original watershed, has

* Pl. III. fig. 2.

been the corrom builder here, and as a consequence it has transferred its allegiance from the southern to the northern drainage system. No valley can be more heartily recommended to anyone desirous of studying corrom formation than this one, owing to the number and beauty of the cones * which enter it from either side. There seems indeed to have been some little competition as to whether the Aikengall Burn or its neighbour to the north should actually succeed in establishing the corrom of the valley; but once the former had settled this point in its favour, it made sure of its conquest by attacking and partially demolishing the work of its rival. One is especially impressed,

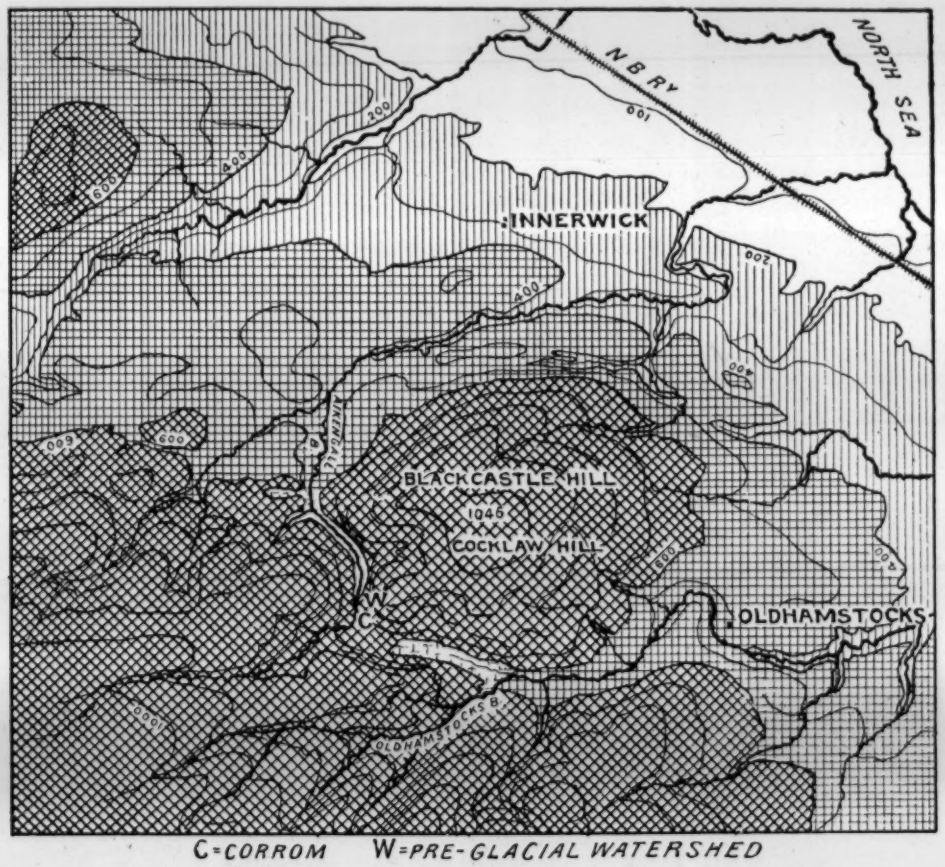



FIG. 6.

both here and in the case of the great Dry Burn valley (Thurston valley) further north, with the probability that the main readjustments, which we can recognise to-day in the glacial drainage system, were virtually completed almost as soon as the opportunity for them arose through the continued retreat of the ice sheet. Thus, to judge from the erosion effects, it would seem that the reversed drainage, initiated upon the corroms of these two valleys, had formerly a much greater volume than at present, and one is led to speculate regarding a time when the streams were apt to be swollen into mighty torrents by the melting of the snows in the hill country. Although a corrom to be permanent must be built of sand, gravel, or some such material, we must not neglect the probability that the corroms of the glacial period may have largely resulted from

* Pl. III. fig. 1.

the piling up of flood-borne ice and snow, mingled and covered with other débris, and that in many cases these temporary constructions may have had a very important influence in shaping the destinies of the drainage system. Before leaving this subject, we would like to notice a particular effect, for which the reversed drainage of the Aikengall Burn may fairly be held responsible. Just to the north of the entrance to the pass, perched upon its western bank, there occur two or three dry valleys, which there can be little doubt were used successively by the marginal stream at a time when the waters of the latter still found an escape southwards through the Aikengall valley. They now "hang" with respect to the latter, since, being streamless, they have not shared in the opportunity of renewed erosion, which it attained through the partial reversal of its drainage.

After what has gone before, there would be no advantage in discussing the history of the Dryburn and Borthwick channels in detail. It suffices to point out that the streams responsible for corrom formation in these two cases are the How Burn and Gore Water respectively.

We may now bring this part of the discussion to a close by observing that the operations of corrom formation are by no means restricted to glacial drainage systems. The circumstances which so greatly favour their growth in the latter are likely to be reduplicated in other situations. Wherever a gently graded valley lies open at its head and no longer supplied with a sufficiency of water, there a corrom is likely to appear; and many a great beheaded valley must have found itself in just such plight, and accepted a corrom as the watershed of its lower reaches. The permanence of the capture thus involved can readily be predicted from analogy with the East Lothian types, for the diversion initiated upon alluvium would, as it were, be fixed by becoming imposed, through continued erosion, upon the rock framework of the country.

It may be well to add here, since the term corrom is now being introduced for the first time into scientific literature, that the definition relates to function and not to origin; it is on this account free from any speculative element. In the beautiful Glen Tarbert example (Ardgour), whence the name has been derived, the delta has accumulated on the surface of a rock watershed. A similar case has been described by Dr Marr * for Dunmail Raise in the English Lake District. The Glen Tarbert and Dunmail Raise deltas are corroms, since they serve as watersheds, quite irrespective of the fact that they cannot be held directly responsible for their behaviour in this respect.

While corrom formation is favoured in the major glacial channels, another modification has affected the less-marked grooves running along the hill slopes and roughly following the contours. Their fate can readily be pictured: the more important side streams have built out their cones into the channels, and thus have furnished themselves with bridge-deltas by which they have won their way to the other side. Once across, they have made good use of the slope and set to work eroding a channel for themselves,

* *Loc. cit.*, p. 143.

often removing all evidence of the manner in which the crossing was made. A capital example of a bridge-delta occurs at Common House, rather more than two miles south-south-west from Spott. Several small streams uniting at this point have well nigh obliterated a portion of a strongly marked contour channel; better still, however, they have later set to work again to destroy the delta, and in the deep gashes that they have cut one may recognise both the nature of the infilling material and the continuation, for some little distance, of the rock walls of the original gorge.

While examples of bridging by deltas can seldom be demonstrated, it is still moderately certain that this operation is responsible in large measure for the reticulate pattern of the East Lothian glacial drainage system.

There is, however, another and distinct way in which a glacial drainage channel may become segmented. Especially in the hilly districts, where pre-glacial features were never obliterated, the major streams have in many cases continued their course straight across glacial drainage channels, merely because the withdrawal of the ice left an open path in this direction.

It is obvious, then, that contour channels are very liable to division. When once this has been accomplished the next step is to provide each segment with its own independent watershed. Here of course an opportunity for corrom formation is afforded, and it is one that, in point of fact, is but seldom neglected.

## V. Evidence regarding the Level of the Sea at the time of the Retreat of the Ice Sheet.

We have not made a special study of the intricate question of the relations of land and sea at the close of the glacial period, but attacking the question from a new standpoint certain results have been attained which we consider to be worth recording.

In the first place, the phenomena which we have been describing are emphatically those of the retreat of an ice sheet obstructing land drainage, and become meaningless if viewed in the light of a submersion theory. In fact, to fix the upper limit which can be assigned to the level of the sea at the time of the retreat of the ice sheet we need only find the lower limit reached by the denudation effects of the land drainage when acting under conditions of glacial constraint. Caution must naturally be exercised in the choice of evidence upon which deductions of this character are to be based, and none but "dry valleys" should be employed for the purpose. All the necessary requirements were found in an exceedingly well marked glacial drainage channel cut in rock and terminating near Eweford, slightly more than a mile south-west from Dunbar; the little water that flows through it merely trickles along a ditch which has been dug to drain the marshes which still occupy portions of its bottom. We may confidently assert that under natural conditions the valley would be streamless; and it is obvious that so far from having been overdeepened since its desertion by the marginal stream, all the processes at work have tended to its obliteration. In spite of this, however, it only

ceases to be a well marked feature on crossing the 75-foot contour line, so that high-water mark at Dunbar, when this channel was being cut, cannot have reached the level of the 100-foot contour line of the present time, and probably did not surpass the 75-foot contour.

In the time at our disposal we were unable to follow up this promising line of evidence, but a visit to St Abb's showed a very similar relation. Lying in the bottom of the hollow which isolates the headland, is a well defined glacial drainage channel. It cuts through rock covered with boulder clay, and is clearly recognisable well nigh as far as the 50-foot contour line.

One further observation may be added which may some day prove of interest in dealing with the raised beaches of the Forth. About half a mile south of the railway at Prestonpans a clearly marked glacial drainage channel cuts through the 150-foot contour line. It in part follows the course of an old glacial groove, but at the same time it undoubtedly shows that the ice sheet at the time of its formation lay to the north and not the south. We see, then, that the great ice sheet continued its process of shrinking into the centre of the valley even to this late stage, and that the bed of the shallow estuary of the Forth served as its last refuge when it had withdrawn from the coastal regions of East Lothian.

Professor P. F. KENDALL and Mr E. B. BAILEY on "The Glaciation of East Lothian South of the Garleton Hills."—PLATE I.

FIG. 1.—Rammer Cleugh, lying south of Deuchrie Dod (the latter not included in the picture). This is the finest dry valley of the district: cut 200 feet deep in rock. Note high-level channel to north of the main valley (left side of the photograph), cut at an earlier stage and blocked during a re-advance of the ice, which led to its abandonment and the opening of the Rammer Cleugh channel proper (pp. 9, 19).

FIG. 2.—Very typical dry valley joining the Spott Burn a short distance above Spott. Note the high-level channel to the south of the main valley (right side of photograph), and probably cut during a temporary re-advance of the ice sheet (p. 11).

Professor P. F. KENDALL and Mr E. B. BAILEY on "The Glaciation of East Lothian South of the Garleton Hills."—PLATE II.

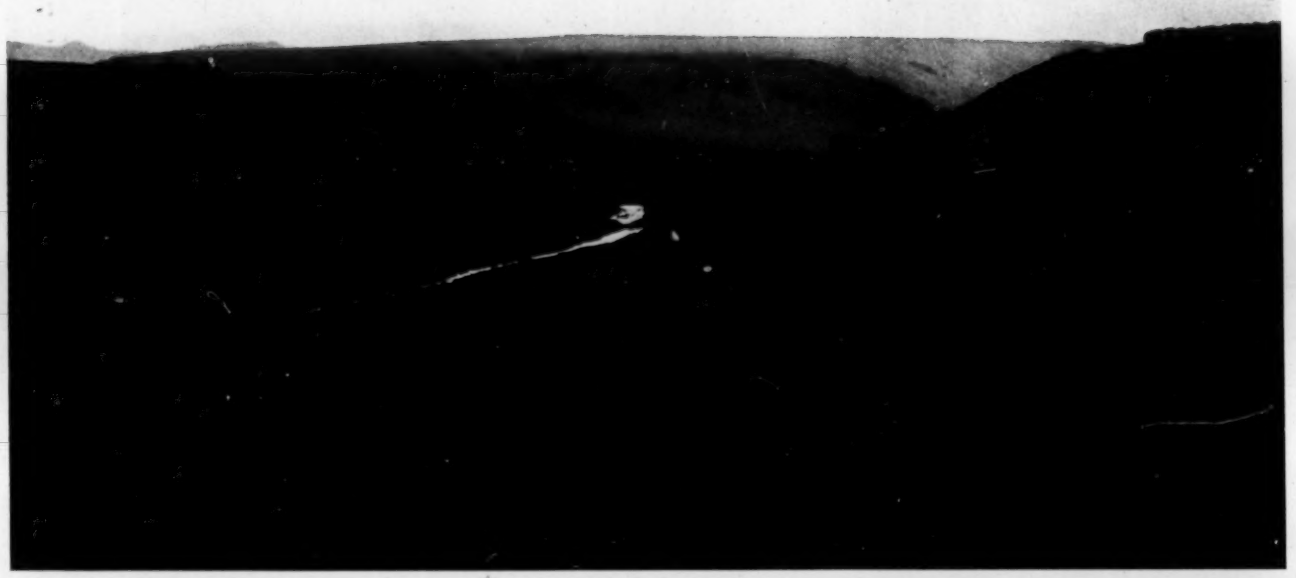


FIG. 1.—Junction of the dry valley shown in Pl. I. fig. 2, with that which carries the Spott Burn. In this case the valley carrying the stream has not been appreciably deepened since glacial times (p. 11).

FIG. 2.—Braidwood Burn. The present stream has cut a minor winding gorge into the bottom of the glacial channel. The latter can still be readily recognised. The material cut through by the burn is Old Red conglomerate (p. 12).

Professor P. F. KENDALL and Mr E. B. BAILEY on "The Glaciation of East Lothian South of the Garleton Hills."—PLATE III.

FIG. 1.—Aikengall Valley. A delta is here shown, deposited by a tributary stream where it enters a dry valley. Note the difference of vegetation on the rock sides of the valley, on its ill-drained bottom, and on the slopes of the delta respectively, and see how the sheep cluster upon the latter (p. 25).

FIG. 2.—The corrom of the Grant's House railway pass, deposited from the small wooded gorge of Blackburnrigg on the far side of valley. Note how the telegraph posts well nigh disappear in the cutting through the corrom and reappear on the further side (pp. 8, 27).

Professor P. F. KENDALL and Mr E. B. BAILEY on "The Glaciation of East Lothian South of the Garleton Hills."—PLATE IV.

FIG. 1.—Sands exposed by Keith Water, one mile north-west of Upper Keith. The top bed in the section consists of 6 feet of boulder clay, which forms the flat on which the railing stands. Note hummocky form of country, due to denudation. The section is, in descending order, boulder clay 6 feet, sand 65 feet, boulder clay 33 feet (pp. 14, 17).

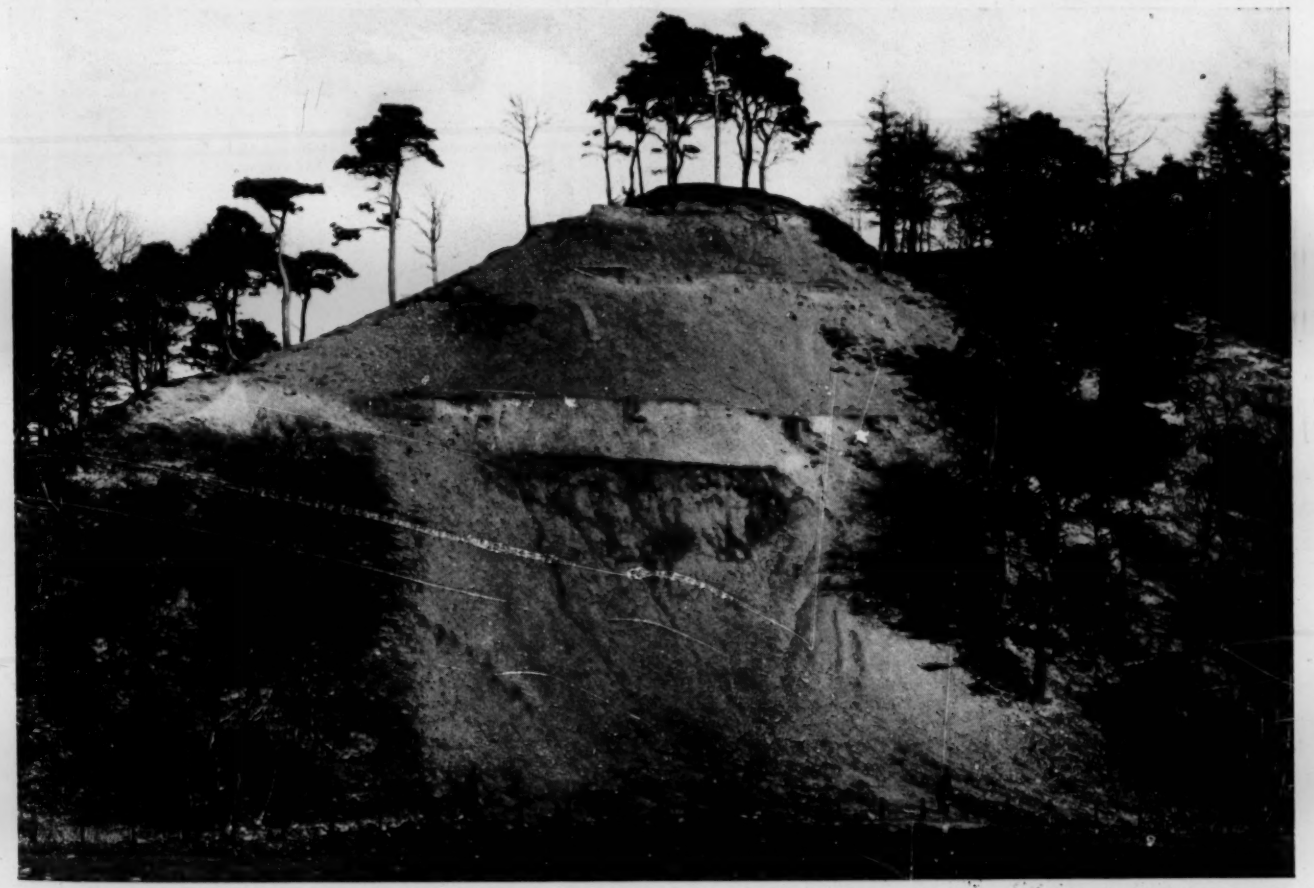


FIG. 2.—Sands exposed by Keith Water in the Red Scar, 1½ miles west of Upper Keith. The bed of boulder clay which caps the section shown in fig. 1 is here overlain in turn by a thick mass of sand. The sands underlying this boulder clay are generally obscured beneath rain-wash, which has been in part cleared to allow of this photograph being taken. The intercalated boulder clay indicates an oscillatory re-advance of the ice sheet which served as the northern boundary of the lake in which the sands accumulated. The section is, in descending order, sand 53 feet, boulder clay 13 feet, sand 15 feet, boulder clay 37 feet (pp. 14, 17).

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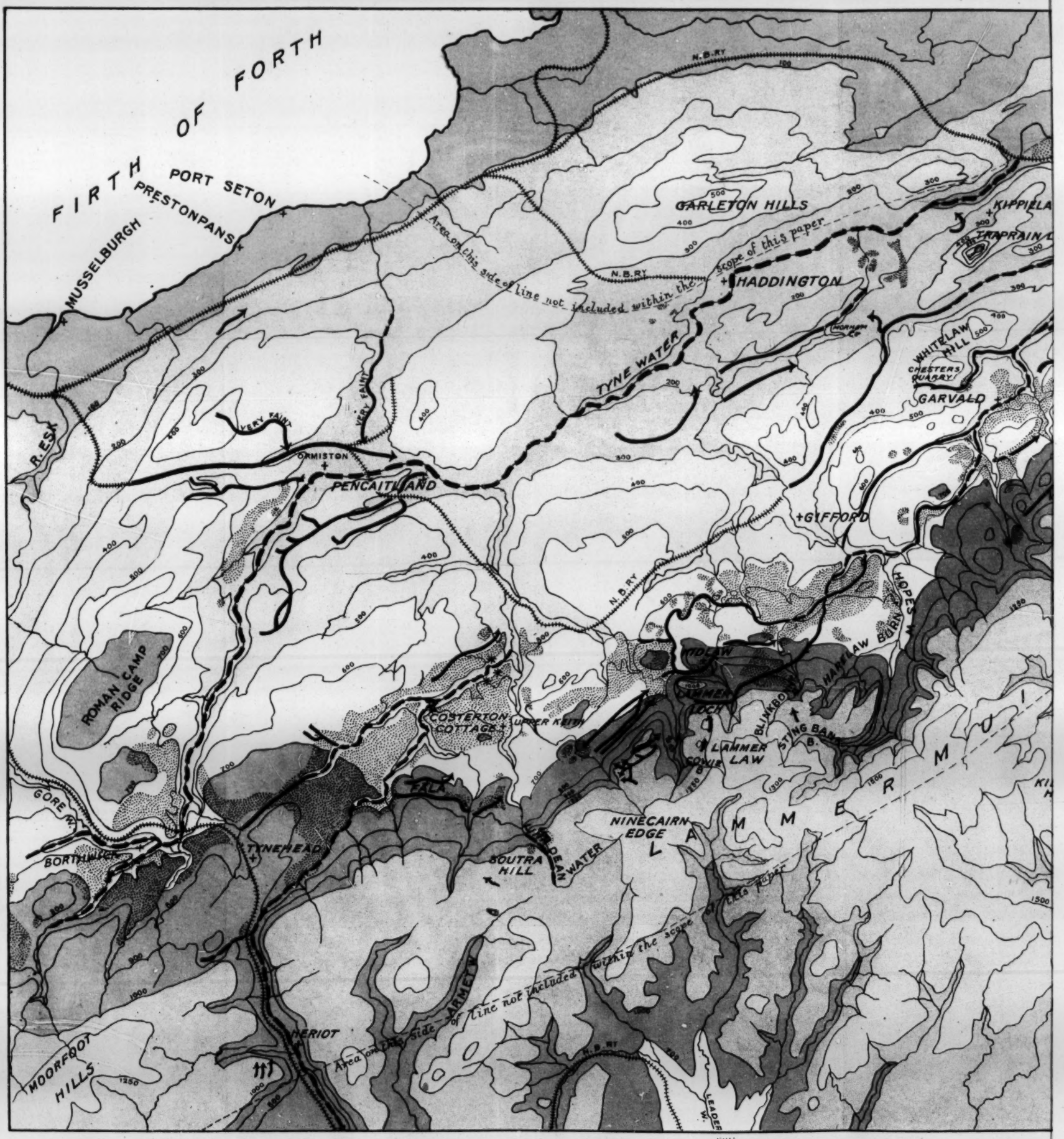
GENERAL MAP SHOWING GLACIAL DRAINAGE CHANNELS AND DISTRIBUT




* *Best sections showing intercalation of Sands and Boulder Clays.* *Sand and Gravel.*
*Heavy solid lines = Dry Glacial Drainage Channels.* *Broken heavy lines = Stream-containing Glacial Draina*

ND DISTRIBUTION OF GLACIAL SANDS AND GRAVELS IN EAST LOTHIAN.

*Z.*
*ing Glacial Drainage Channels.*

M'Farlane & Erskine, Lith. Edin.

# II.—The Plant Remains in the Scottish Peat Mosses.

By **Francis J. Lewis**, F.L.S., Lecturer in Geographical Botany, University of Liverpool. *Communicated by* Professor Geikie, LL.D., D.C.L., F.R.S. (With Four Plates.)

## PART III.

### The Scottish Highlands and the Shetland Islands.

(MS. received June 25, 1907. Read July 8, 1907. Issued separately November 18, 1907.)

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During 1904 and 1905 the author investigated the plant remains of the peat deposits in certain areas of the Southern Uplands and the Highlands. The present paper deals with similar work over large peat-covered areas in the E. and N.W. Highlands, Shetland Islands, and the Outer Hebrides.

Perhaps the most interesting feature found in the course of the work is the evidence of constant change in the character of the vegetation which has successively covered the peat areas of Scotland. Many areas in different parts of the country have been examined in order to ascertain if this succession can be accounted for by local changes in physical conditions, or whether it represents stages in a long cycle of secular changes in climate, and consequent plant migrations.

If the successive changes in vegetation are constant over large areas in different parts of the country, some of the main facts for a distributional history of the British flora are available.

The scope of such an inquiry is limited by the comparatively small flora characteristic of peat, but, on the other hand, the peat deposits possess certain advantages, for the strata are laid down in a regular series, and thus correlation of the strata in one district with those in another does not usually present any serious difficulty.

As all the peat deposits are stratified, it becomes a matter of interest to examine the plant remains contained in the several strata. The search might be expected to yield

evidence of interest both to botany and geology. On the one hand, it will give the *facies* of the vegetation which has during successive periods covered the peat mosses; and on the other, much may be learnt of the climatic conditions from the presence of certain sets of characteristic plants in the strata.

The work of the last three years has shown that many of our peat mosses began their growth under arctic conditions, and thus, during some stage of the glacial period. The successive strata in such areas will then contain the salient features of the types of vegetation which have existed from that time down to the present. Direct palæontological evidence will then be available for a long period of time during which, geologists are agreed, many climatic changes have occurred, though the amplitude of such changes is still a matter of controversy. Differences in climatic conditions of small amplitude would certainly affect the character and distribution of vegetation to a greater degree than the alluvial drifts which were deposited whilst those changes were in progress.

Before giving a detailed description of the deposits examined during the field work in 1906 it may be well to review briefly the results obtained in 1904 and 1905.

During the examination of large areas of peat it is found that certain datum lines make their appearance in all the districts. The most prominent datum lines are two beds of buried forest separated by a considerable thickness of intervening peat which is always free from tree remains. These two forest beds—the lower and the upper buried forest—are found in all large and deep peat mosses above 100 feet altitude which have been examined in the south of Scotland. The lower forest consists of birch, hazel, and alder; the upper generally of pine. These forest remains are so well marked, and persist over so wide an area, and are underlaid and overlaid by such closely similar strata in the different districts, that there can be no doubt they represent true horizons.

The upland valley deposits of the south of Scotland show a bed of peat containing the remains of an arctic flora between the lower and upper forest bed. This is considered to indicate a decided change in conditions between the dying away of the lower forest and the appearance of the upper forest. Those peat areas below 300 feet, and near the sea in Kirkcudbrightshire and Wigtownshire, contain beds of swamp vegetation between the two forest beds instead of arctic plants, but these swamp plants are such that attain a high latitude in Europe and Asia. In the south of Scotland the peat thus shows a transition from a forest vegetation to one characteristic of Arctic regions, and this gradually gives place to a second forest vegetation, which in turn is displaced by bog and moorland vegetation persisting to the present time.

The Highland areas so far investigated reproduce the later stages found in the Southern Uplands, but the earlier beds are wanting. The basal layers of the peat contain the remains of an arctic vegetation similar to that met with between the two forest beds in the south. Above this, lies the upper peat bog covered with the upper forest and recent peat. The upper forest consists of two distinct zones separated by 1–3 feet of Sphagnum peat quite free from traces of wood. This is a feature of constant occurrence in the Highlands, but it has not been found in the south of Scotland.

*Field Work.*—All the peat areas examined lay some distance from crofts or villages, and the strata showed no sign of having been disturbed by human agency. Sections were cut down through the successive strata until the underlying rock, gravel, or sand deposits were reached. Each section was made just large enough to work in conveniently. Over areas where the peat was of moderate depth the sections were usually 8 or 9 feet in length and 4 feet wide. In some districts, such as the Shetlands, where the peat proved to be 18–19 feet in depth the sections had to be made 17–20 feet in length to allow a series of platforms to be left at each end, upon which the peat from near the base of the section could be placed. In some of the areas a good deal of difficulty was experienced in cutting through the upper forest of pine. The timber proved to be so large and tough, and so closely packed, that it was impossible to cut through it with a spade, and it was necessary to clear away the large trunks and roots of the pine with the aid of an axe and saw before the underlying peat could be excavated.

In the examination of the peat samples brought back to the laboratory, much help has been obtained by the use of the method described by Gunnar Andersson (1). Samples of the peat are treated with nitric acid, which completely oxidises the material, loosens, and at the same time bleaches it. The peat is then placed in sieves and the loose debris washed away, leaving any seeds and fruits which it may contain. Fragile leaves are usually broken into fragments during this process, and they can best be obtained by dissecting them out from the peat without previous treatment.

The following areas are described in this paper:—

1. Valley deposits in the Highlands.
   - (*a*) The Parph, Cape Wrath.
   - (*b*) Assynt district of Sutherlandshire.
2. Upland deposits in the Highlands.
   - (*a*) Water of Lee district, Grampians.
   - (*b*) Rannoch Muir.
3. The Outer Hebrides.
   - Eastern, Central and Western peat bogs of Lewis.
4. The Shetland Islands.
   - Walls, and central districts of the mainland.

## 1. Valley Deposits in the Highlands.

(*a*) *The Parph, Cape Wrath* (one-inch Ordnance Survey—sheets 113, 114).—This area is roughly triangular in shape, lying between Cape Wrath, the Kyle of Durness, and Loch Inchard. The northern part towards Cape Wrath consists of a series of somewhat rounded hills rising to 1500 feet with broad valleys between, covered with peat which extends far up the hillsides. Farther to the south the country becomes rugged, and some of the hills, such as Creag Riabhach, show very fine rock exposures, but peat still occurs in the valleys.

A good bird's-eye view of nearly the whole district can be obtained from the summit of Fashven, six miles south of Cape Wrath. Seen from here, the peat deposits appear as a broad sheet covering all the lower part of the country, only the bare Torridonian sandstone summits being free from peat. In the more exposed situations denudation has been active, large patches of peat are bare of vegetation and frequently under water.

The surface of the peat and the configuration of the peat-hags on the summit of Maovally bear witness that the action of the wind is a most important factor in the denudation of the peat. On the hill slopes, particularly those that face N.W., the rhizomes of Junceae all lie on little ridges of peat held together by the numerous fine roots of the plants, the peat having been completely blown away from the sides and tops of the rhizomes. The summit of Maovally (984 feet) forms a small plateau about one-third mile across. This was originally covered with deep peat, which now has been washed away to forms exactly resembling sand-dunes—the longer axes of the dunes all pointing N.W. to S.E., the direction from which the strongest gales occur.

The peat over this area supports a vegetation of *Scirpus cæspitosus* * and stunted Calluna, forming an association much like that described by PETHYBRIDGE and PRAEGER (2) on some of the Irish moors in Wicklow. No trees of any kind now occur in the district.

The chief geological formations are Torridonian Pebbly Grits and Gneiss (Lewisian).

Sections and borings were taken in all the valleys and up the hillsides for a distance of nine miles south of Cape Wrath. Owing to denudation, natural sections are fairly numerous, particularly in the north. The peat was found to be of moderate depth, varying from 8–14 feet, the depth gradually increasing as some of the broad open valleys near Cape Wrath were examined.

A preliminary examination of the peat banks throughout the district showed no trace of the upper pine forest except at one or two places to the east of Cape Wrath, where a few stunted pine trees were observed, but these were not comparable in size to those found elsewhere in the upper forest.

The drainage system of the district is roughly divided into an eastern and western area by a succession of hills running south from Cape Wrath.

Three typical sections may be taken from the western area.

SECTION I. :—

| CHARACTERISTIC PLANTS. | ACCOMPANYING PLANTS. |
|---|---|
| 1. *Scirpus cæspitosus.* | 1. ... |
| 2. *Calluna vulgaris.* | 2. ... |
| 3. *Betula alba*—small shrubs. | 3. *Calluna vulgaris.* *Eriophorum angustifolium.* |
| 4. *Calluna vulgaris.* | 4. ... |
| 5. Sphagnum. | 5. *Eriophorum vaginatum.* |
| 6. *Empetrum nigrum.* | 6. Sphagnum. |
| 7. *Salix reticulata.* | 7. *Potentilla Salisburgensis.* |
| 8. Dry hard peat mixed with fine angular sand ; a few small fragments of stems, but no other recognisable remains. | 8. ... |

Rock.

* The nomenclature of Hooker's *Student's British Flora*, third edition, is followed throughout.

SECTION II. :—

| CHARACTERISTIC PLANTS. | ACCOMPANYING PLANTS. |
|---|---|
| 1. *Scirpus cæspitosus.* | 1. *Eriophorum angustifolium.* *Calluna vulgaris.* |
| 2. *Betula alba*—small shrubs. | 2. *Eriophorum sp.* (abundant). |
| 3. *Betula nana.* | 3. *Empetrum nigrum.* |
| 4. *Salix Arbuscula.* | 4. *Empetrum nigrum.* |
| 5. *Potentilla Comarum.* | 5. *Carex ampullacea.* |

Peaty sand and pebbles.
Sand.

SECTION III. :—

| CHARACTERISTIC PLANTS. | ACCOMPANYING PLANTS. |
|---|---|
| 1. Scirpus, Sphagnum. | 1. Calluna (fairly plentiful). |
| 2. *Betula alba* (small). | 2. ... |
| 3. *Empetrum nigrum.* | 3. ... |
| 4. *Empetrum nigrum.* | 4. *Salix Arbuscula.* |
| 5. *Potentilla Comarum.* | 5. *Salix Arbusculu, Carex sp.* |

Peaty sand.

The sequence of strata in these sections agrees closely. The upper forest is everywhere missing, but a constant feature is the presence of a shrubby growth of birch which in some cases extends from the Empetrum and Salix beds up to the recent Scirpus, Eriophorum, and Sphagnum bed. The birch is always of very small size and mixed with much Eriophorum, Calluna, and Sphagnum. In fact, the evidence points to the birch growth representing a period of peat formation or peat bog conditions, and differs very much in this respect from the features found in the lower and the upper forest. It may be recalled that a similar scrub birch mixed with peat bog plants was recorded from many other districts in the Highlands in 1906 (3). In those districts, however, the upper forest of pine was well marked and occurred above the scrub birch and separated from it by some thickness of Sphagnum. Before fully discussing the sequence in this district, typical sections may be given from the eastern drainage area.

SECTION I. :—

| CHARACTERISTIC PLANTS. | ACCOMPANYING PLANTS. |
|---|---|
| 1. Scirpus peat. | 1. ... |
| 2. Calluna peat. | 2. ... |
| 3. *Betula alba* (scrub). | 3. *Eriophorum vaginatum*, Sphagnum. |
| 4. *Eriophorum vaginatum.* | 4. *Empetrum nigrum.* |
| 5. *Empetrum nigrum.* | 5. *Salix Arbuscula, Sagina nodosa.* |
| 6. *Potentilla Comarum.* | 6. ... |
| 7. Structureless peat. | 7. ... |

SECTION II. :—

| CHARACTERISTIC PLANTS. | ACCOMPANYING PLANTS. |
|---|---|
| 1. Scirpus. | 1. ... |
| 2. *Betula alba.* | 2. ... |
| 3. *Empetrum nigrum.* | 3. *Menyanthes trifoliata.* |
| 4. *Salix Arbuscula.* | 4. *Empetrum nigrum.* |

Rock.

SECTION III. :—

| CHARACTERISTIC PLANTS. | ACCOMPANYING PLANTS. |
|---|---|
| 1. *Scirpus cæspitosus.* | 1. Sphagnum. |
| 2. Stiff structureless peat, having apparently been much exposed to denudation before being covered by the overlying Scirpus. | 2. ... |
| 3. Calluna peat. | 3. ... |
| 4. *Betula alba* (scrub). | 4. ... |
| 5. *Empetrum nigrum.* | 5. *Salix Arbuscula.* |

Peaty sand and rock.

An interesting feature here is the frequent presence of peat underlying the Empetrum and *Salix Arbuscula* and *S. reticulata* zones. An examination of this basal layer in the field showed no recognisable plant remains, but samples tested with nitric acid in the laboratory yielded seeds of *Potamogeton natans*, *P. prælongus*, *P. rufescens*, *Menyanthes trifoliata*, *Ranunculus repens*, *R. flammula*—in fact, the remains of an aquatic vegetation. All these species have a wide distribution at the present time, but their presence at the base of the peat suggests that the summers of that time were fairly warm and were long enough to allow these aquatic plants to seed freely. The shallow character of this bed and its absence in many of the sections rather points to its belonging to the same stage as the overlying Salix and Empetrum beds. The same feature has been met with underlying the arctic bed in the Shetlands, and its significance will be discussed more fully when dealing with that area.

The general succession of vegetation here compares very closely with the succession in the Inverness-shire, Easter Ross, and Caithness-shire areas described in 1906 (3). An important difference is the absence of the upper forest bed. This zone is generally present in the south of Scotland and in the Highlands; it has been noted as far north as the valley of the river Dionard immediately to the south of this district, and is occasionally present in the peat on the moors round Loch Eriboll, but it has not been found in any of the peat areas examined in the Hebrides and the Shetlands. During the examination of the peat on the Caithness-Sutherland border the upper forest zone is generally found to be present but the pine is frequently replaced by birch. The northern boundary of this forest bed is evidently approached in the Cape Wrath district, as here, pine remains tend to become stunted and birch frequently takes its place. In most districts the upper forest bed dies out before the northern coast is reached.

The scrub birch described from this district must not be confused with the lower or the upper forest bed, for the wood in all cases is very small, not plentiful, and is always mixed with quantities of Eriophorum, Sphagnum, and Scirpus remains. Moreover, it does not correspond in position to either the lower or upper forest bed. The sections show that the basal Salix and Empetrum beds were gradually replaced by peat bog associations, amongst which scrub birch managed to find a footing.

As the peat deepened, the birch disappeared and Eriophorum and Sphagnum became dominant over the area. That conditions at this period were not suitable for the growth of birch forest is shown by the fact that the birch remains are often absent

in the more exposed situations; are always larger and persist for a greater depth in the peat lying in valleys which face to the south and east; whilst on the hill slopes and in valleys which run north and north-west the remains are either very small or else entirely absent.

This is in great contrast to the distribution of the lower or the upper forest beds, which are often found in positions now unfavourable for tree growth, such as the bleak and treeless Outer Hebrides, and at altitudes of 3000 feet in the Highlands.

(*b*) *The Assynt District of Sutherland.*—This district is dominated on the east by the *massif* of Breabag, Conaveall, Ben More Assynt and Glasven, which rise to an average altitude of 3000 feet. An extensive region of undulating moorland lies to the south and west with Suilven, Canisp, Cul Mor, and Cul Beag rising to about 2600 feet, at intervals of some miles, as isolated and precipitous hills. The general elevation of the moorland is from 100 feet to 700 feet, and most of it is covered with deep peat, but the hills are bare and rocky. The peat is very little broken up by denudation, and the moors, intersected by scores of lochs, present a smooth and flowing aspect.

Two areas were examined: 1, peat lying on quartzite in the valley of the river Loanan, to the south of Loch Assynt; and 2, an area near Loch Urigill about nine miles farther south than the first area.

1. *Peat in the Loanan Valley.*—The peat lies 300 feet above O.D. between Canisp on the west and the limestone cliffs of Stonechrubie on the east. The chief vegetation now is Calluna, *Scirpus cæspitosus*, *Eriophorum vaginatum*, *Narthecium ossifragum*.

The peat varies in depth from 5–8 feet; the surface is but little denuded, and closely covered with vegetation.

Many sections taken over the southern and higher part of the moss showed the following strata :—

| Characteristic Plants. | Accompanying Plants. |
|---|---|
| 1. *Scirpus cæspitosus.* | 1. *Eriophorum vaginatum.* |
| 2. *Pinus sylvestris.* | 2. *Calluna vulgaris.* |
| 3. Sphagnum. | 3. Traces of scrub, *Betula alba.* |
| 4. *Betula nana.* | 4. *Empetrum nigrum.* |
| 5. *Betula alba* of large size. | 5. *Corylus Avellana.* |
| 6. Moss peat. | 6. *Calluna vulgaris* (abundant). |

Stone pavement.

This sequence shows three points of interest. Firstly, there are no arctic plants at the base of the peat. We may infer from this, either that the record of the earlier post-glacial vegetation is missing, or that the moss peat represents swamp conditions which prevailed at this place immediately after the retreat of the latest glaciers. The abundance of Equisetum remains in the basal zone in some of the sections taken in this area rather points to the latter view as being more probable.

The second interesting feature is the presence of a bed of *Betula alba* (No. 5) and the *Pinus sylvestris* (No. 2) zone. The two layers of large trees separated by about 1–1½ feet of peat closely correspond to the features observed in many Highland districts.

In position the layer of Pinus (No. 2) and *Betula alba* (No. 5) agrees exactly with the upper and the lower layer of pine separated by 18 inches of Sphagnum peat recorded from the Spey-Findhorn watershed, Coire Bog, and the Findhorn-Nairn watershed (3). Here, however, the lower layer of trees consists of *Betula alba*, and there are also traces of this tree in the *Pinus sylvestris* zone. The occurrence of abundant *Betula nana* between two such forest beds is of some interest, as similar plants in the same relative positions have been observed in the mosses of the Grampian mountains and the Caithness-Sutherland border.

The third noteworthy feature is the fact that *Betula alba* tends to replace *Pinus sylvestris*. The same feature has been noted near the northern boundary of the upper pine forest.

The northern and lower-lying peat of the moss yielded much the same sequence, although, as one would expect, some of the details differ, as the following section shows :—

| Characteristic Plants. | Accompanying Plants. |
|---|---|
| 1. Scirpus peat. | 1. Sphagnum. |
| 2. *Pinus sylvestris.* | 2. *Calluna vulgaris.* |
| 3. *Scirpus cæspitosus.* | 3. ... |
| 4. *Betula alba* of large size. | 4. *Corylus Avellana.* |
| 5. *Rhacomitrium lanuginosum.* | 5. Stunted Calluna, Scirpus. |
| 6. Sandy peat with much *Equisetum sp.* | 6. *Hypnum sps.* |

Sand and rock.

It will be noticed that here the whole of the peat between the two forest beds is formed from Scirpus without any trace of *Betula nana*.

2. *Peat in the neighbourhood of Loch Urigill.*—The peat occurs upon open undulating moorland to the west of the Ben More Assynt, and Breabag ridges. The mosses are generally level, and peat appears to be forming at the present time. Sections were taken round Loch Urigill and Crom Allt—a stream draining into the southern end of Loch Urigill.

The upper forest zone is poorly represented, and pine is generally replaced by birch. Moreover, none of the sections showed any trace of arctic plants at the base, thus indicating that the earlier stages are missing.

The general sequence is as follows :—

| Characteristic Plants. | Accompanying Plants. |
|---|---|
| 1. *Scirpus cæspitosus.* | 1. Calluna, Sphagnum. |
| 2. *Pinus sylvestris.* | 2. Calluna. |
| 3. *Scirpus cæspitosus.* | 3. *Betula nana*, Sphagnum. *Rhacomitrium lanuginosum.* |
| 4. *Betula alba.* | 4. *Corylus Avellana.* *Salix purpurea.* |

The *Pinus sylvestris* bed is absent in many of the sections, but the *Betula alba* zone (No. 4) is generally well marked.

It should be pointed out that the peat is continuous for many miles to the south

and west, and that last year it was possible to examine only a comparatively small area, so that arctic vegetation may be present in other parts of the district. The sections are, however, of interest, as they confirm the widespread character of the upper forest beds, and also give evidence that this district is on the confines of the western boundary of the upper forest.

## 2. Upland Deposits in the Highlands.

(*a*) *The Forfarshire Grampians* (one-inch Ordnance Survey—sheet 65).—This area shows a great extent of peat, covering both the summit plateaux and sides of the mountains.

The most characteristic plant occurring at present on the peat areas is *Scirpus cæspitosus*, and the general character of the vegetation is somewhat similar to that in Skye. Mixed with *Scirpus cæspitosus* are Calluna in small stunted patches, *Eriophorum vaginatum* (scanty), Sphagnum, *Cladonia rangiferina* (abundant), and in the drier places *Juncus squarrosus*. Many of the flat summit plateaux have probably been the site of lochs which are now filled with peat. The vegetation in such positions is somewhat different, the chief plants being *Rhacomitrium lanuginosum*, forming large beehive-shaped mounds, Sphagnum, *Eriophorum vaginatum*, *E. latifolium*, *Scirpus cæspitosus*, occasional stunted plants of *Erica Tetralix*, *Calluna vulgaris*, and much *Drosera intermedia*, with a few plants of *Pinguicula vulgaris*.

The whole area is under deer forest. Sections were made on the summit plateaux round the head of Glen Lee, Glen Mark, and Unach Water, the altitude varying from 2000 feet to 2700 feet.

Three types of mosses were found in different areas in this district, and sections are given to illustrate each type.

I. In the corrie between Drumhilt and Hunt Hill at 2000 feet:—

| Characteristic Plants. | Accompanying Plants. |
|---|---|
| 1. *Scirpus cæspitosus.* | 1. *Eriophorum vaginatum.* |
| | Sphagnum. |
| 2. *Pinus sylvestris.* | 2. *Calluna vulgaris.* |
| 3. *Carex sps., Salix Arbuscula.* | 3. *Betula nana.* |
| | Mosses. |
| 4. *Betula alba.* | 4. *Calluna vulgaris.* |
| 5. Mossy peat, with traces of *Betula alba.* | 5. *Viola palustris.* |

Sand and gravel.

II. On the moors round Unach Water at 2500 feet:—

| Characteristic Plants. | Accompanying Plants. |
|---|---|
| 1. *Eriophorum vaginatum.* | 1. *Scirpus cæspitosus* (abundant). |
| 2. *Calluna vulgaris.* | 2. ... |
| 3. Structureless peat. | 3. ... |
| 4. *Betula alba.* | 4. *Calluna vulgaris.* |

Sand and gneissose rock.

III. Near Slidderies Burn at 2250 feet :—

| Characteristic Plants. | Accompanying Plants. |
|---|---|
| 1. *Eriophorum vaginatum.* | 1. *Calluna vulgaris.* |
| 2. *Calluna vulgaris.* | 2. ... |
| 3. *Potentilla Comarum.* | 3. *Salix Arbuscula.* |
| 4. *Betula alba* (large). | 4. *Viola palustris, Ajuga reptans.* |
| 5. *Salix reticulata, S. Arbuscula.* | 5. *Equisetum sps., Carex sps., Sedum Rhodiola.* |

Boulder clay.

These three types are instructive, inasmuch as they show that peat of very different age may be encountered in dealing with a large district.

In Section III. arctic vegetation occurs at the base of the peat resting upon boulder clay, but this is not the case in Sections I. and II., which are evidently younger than the third type.

In Section III. *Betula alba* with *Viola palustris* and *Ajuga reptans* overlies the basal arctic vegetation ; in Sections I. and II. a similar vegetation occurs at the base of the peat.

The remaining beds in the three sections show remarkable agreement in their main features, but they exhibit particularly interesting features in connection with the upper forest. The upper forest is, in this district, as in so many others in the Highland areas, in two distinct zones separated by about 2 feet of peat. The upper tier in Section I. is composed of pine and the lower of birch. The peat between shows a very different kind of vegetation, such plants as *Salix Arbuscula*, *Potentilla Comarum*, *Betula nana*, Carex sps., replacing the birch and pine. The intercalation of such arctic or sub-arctic plants between the two layers of the upper forest is not confined to the Grampians, as it also occurs in Caithness and Sutherland. The lower tier of forest forms a good datum line, as it is present in all three types of mosses. The intercalated arctic plants above are also present in the first and third type, whilst in the second a zone of structureless peat occurs at this horizon. In the second and third type the upper tier of forest is wanting, but in both cases a bed formed almost entirely of Calluna stems occurs at the same level in the peat.

The presence of intercalated arctic or sub-arctic vegetation seems to give strong support to the view that there was a change of conditions between the growth of the lower and upper tier of the last forest period. At the present day such plants as *Salix Arbuscula*, *Betula nana*, do not form moors at the same elevation and under the same climatic conditions as a forest of pine or birch. The observations of W. G. Smith (4) upon areas bordering the one under consideration show that the birch forest and accompanying vegetation extends up to about 1500–1750 feet, whilst the highest moors at 2000–3000 feet are dominated by an association formed of Calluna and *Vaccinium Myrtillus* with *Cornus Suecica*, *Rubus Chamæmorus*, *Betula nana*, *Lycopodium annotinum*, *Loiseleuria procumbens.* In addition to this it should be remembered that most of the woods occurring so high as 1750 feet are of small extent and have clearly been planted, and all of them are protected either by dry stone walls or by some natural feature ; and as far

as I know pine or birch woodland does not occur on any 2000-feet summit in the Highlands. In short, the distribution of pine and birch forest and sub-arctic moorland is well defined, and the two associations are not now found intermixed at the same elevations and under precisely the same climatic conditions.

This alternation of forest, arctic moorland and forest, is either good evidence of a change of climatic conditions, or we must agree that in past times the different types of vegetation, for some unknown cause, bore altogether different relations to one another. The latter view can hardly have much to recommend it, and if accepted, would negative all stratigraphical evidence.

We see, then, that whilst some types of the Eastern Grampian mosses began their history under arctic conditions, other types began to form during the latter stages of the upper forest period. In each type the younger strata are the same. Arctic plants occur between the two zones of the upper forest in several other areas in the Highlands, whilst in nearly all, the upper forest is divided into two zones, separated by some depth of peat indicating wet conditions. The presence of forest at such altitudes also indicates a different altitudinal range to that of the present day, but this will be discussed when describing the geographical distribution of the zones.

(*b*) *The eastern Peat of Rannoch Muir* (Ordnance Survey—sheet 54).—The moor of Rannoch forms an extensive undulating region lying at 900–1500 feet, bounded on the west and south by mountains rising to 3000–4000 feet, on the north by a chain of hills rising to over 2000 feet. The drainage from these great watersheds passes westward across the moor to Loch Rannoch, and thence by the river Tummel to Central Perthshire.

The greater part of the moor is covered with deep peat, and this is particularly the case in the area south of Loch Lydoch and along the Allt Lochain Ghaineamhaich—a stream draining into the western arm of Loch Lydoch. In some places the peaty covering is interrupted by beautiful sets of moraines, whose steep sides are often covered with thin peat formed chiefly of Calluna. Observations were confined to the eastern part of the moor, to the south and west of Loch Lydoch—an area extending to about six miles by three miles.

The vegetation over the peat-covered areas is dominated by *Scirpus cæspitosus*, with stunted Calluna, *Eriophorum vaginatum* (generally distributed), *Rhacomitrium lanuginosum* (very abundant), Sphagnum (abundant on many of the spongy bogs near stream heads, particularly in the western part of the moor). The peat is now much denuded, and waste appears to be more rapid than growth. This is seen by the frequent exposure of the upper forest, although, where denudation has not been so active, it is buried beneath 4 feet of peat. Some difficulty was experienced owing to the amount of water in the peat, and many sections had to be abandoned from this cause. The general depth of the mosses ranged from 8–14 feet.

Some interest attaches to the examination of an area of this description, as owing to the probability of the lower-lying or badly-drained portions being frequently flooded, much less regularity might be expected in the plant strata than on rounded hills and in

broad, well-drained valleys. This expectation was fully borne out, but such differences were chiefly confined to the lower layers of peat. The upper forest is present over all the area examined and forms an excellent datum line (Plate IV. fig. 11). Sections taken to the S.E. of Loch Lydoch showed the following beds :—

| Characteristic Plants. | Accompanying Plants. |
|---|---|
| 1. *Scirpus cæspitosus.* | 1. Sphagnum. |
| 2. *Pinus sylvestris.* | 2. *Calluna vulgaris.* *Vaccinium Myrtillus.* |
| 3. Sphagnum. | 3. *Betula alba* twigs. |
| 4. *Betula alba* (shrubby growth). | 4. *Eriophorum vaginatum.* Sphagnum. |
| 5. Structureless peat containing traces of Sphagnum. | 5. ... |

Granitic sand and gravel.

Between Loch Lydoch and the Black Corries the lower layers of the peat show a different vegetation :—

| Characteristic Plants. | Accompanying Plants. |
|---|---|
| 1. Sphagnum. | 1. *Scirpus cæspitosus.* |
| 2. *Pinus sylvestris.* | 2. *Calluna vulgaris.* |
| 2. Mossy peat with much *Phragmites communis.* | 3. ... |
| 4. *Betula nana.* | 4. Sphagnum, *Equisetum sp.* *Potentilla Comarum.* |

Further west, towards Kingshouse, the general sequence remains the same, but the basal beds yield a few other plants.

| Characteristic Plants. | Accompanying Plants. |
|---|---|
| 1. *Scirpus cæspitosus.* | 1. Sphagnum, *Eriophorum vaginatum.* |
| 2. *Pinus sylvestris.* | 2. *Calluna vulgaris.* |
| 3. *Scirpus cæspitosus.* | 3. Sphagnum, Eriophorum. |
| 4. *Grimmia sp.* | 4. |
| 5. *Betula nana.* | 5. *Salix Arbuscula, Empetrum nigrum, Arctostaphylos alpina.* |
| 6. Equisetum, Sphagnum. | 6. Many broken and water-worn fragments of *Betula alba.* |
| 7. ... | |

Sand and clay, with angular stones.

It is evident from the plant remains that much of the moor of Rannoch peat began to form under marsh conditions. Quantities of water-worn birch fragments occur towards Kingshouse, not only with the marsh plants at the base of the peat, but in the drift below. The wood bears traces of prolonged water action, and although many of the fragments are small twigs, some are larger and evidently belong to fairly large trunks of birch mixed with fragments of birch bark. This wood evidently did not grow *in situ*, and it can hardly represent the drift of a few streams, as the material occurs in many sections spread over a large area. At the same time, this drift-wood cannot represent debris from the upper forest, as that is a well-marked zone in the higher layers of peat and separated from the drift-wood under discussion by strata-containing arctic plants. The character and position of this material certainly suggests derivation from older beds which existed here before the present peat mosses began to form.

The peat immediately above the basal marsh vegetation forms a well-marked horizon, as it is entirely made up of the remains of *Betula nana*, stems and leaves, and scales of the female catkins, and *Salix Arbuscula*, *Empetrum nigrum*, and *Arctostaphylos alpina*. None of these plants are characteristic of swamps or marshes, but *Betula nana* occurs in peat bogs at fairly high elevations, and the other plants are abundant on mountain slopes and summits. Comparing the *Betula nana* bed and the *Pinus sylvestris* bed (Nos. 5 and 2) in the last section, it is evident from the plants that the peat of these two beds was not laid down under the same conditions. No changes in the drainage or the character of the peat would cause a forest of *Pinus sylvestris* to replace a close growth of *Betula nana*, *Salix Arbuscula*, *Empetrum nigrum*, and *Arctostaphylos alpina*. At the present day these two types of vegetation have their own altitudinal range, and are never found associated. In the case of the arctic bed (No. 5) we are dealing with a depression of the arctic zone. The *Pinus sylvestris* bed represents a return of the forest zone to at least its present altitudinal limits.

The upper forest bed (zone No. 2) does not apparently show the double tier of trees so characteristic in most of the Highland areas. The only indication of such a feature is in Section I., where *Pinus sylvestris* is underlaid, first by a Sphagnum bed and then by a layer of birch. But the wood is small in size, it is absent in many sections; and where present it is always mingled with quantities of Eriophorum and Sphagnum; a condition of things very different from that of a true forest bed, where the peat contains dry moorland plants and shows unmistakable signs of having been accumulated slowly. On the other hand, this shrubby birch agrees in character and in position with that described from the Spey-Findhorn and Findhorn-Nairn watersheds, Coire Bog, and Caithness in 1906 (3). The general sequence of the peat in this area agrees very closely with that in the areas just mentioned.

### 3. The Outer Hebrides.

*Peat in the Island of Lewis* (one-inch Ordnance Survey—sheets 99, 105).—Following on the examination in 1905 of the peat in North Uist and Skye, it was decided to examine part of the extensive peat in the Lews to see what light it would throw upon problems raised by the peat in Skye and Uist. In addition, the distance of the island from the mainland and its position on the extreme N.W. edge of the Continental plateau made it desirable to ascertain if the strata represented on the mainland also appeared there.

The whole of the island north of Loch Erisort is practically peat-covered, with the exception of small cultivated areas near the townships on the coast.

For a distance of 32 miles northward of Loch Erisort the island does not rise above 900 feet, and most of it is under 400 feet. The central portion is almost level, and forms an unbroken peat bog over which are scattered scores of lochs. In the southern region towards Loch Erisort they are so numerous that the island consists of almost

equal portions of land and water. Whilst many of the lochs are deep with rocky basins, others are merely hollows in the deep peat. The condition of the peat over this great area (where the conditions for peat formation are perhaps more favourable than in any other part of Great Britain) entirely confirms the conclusions reached by GEIKIE (5) many years ago, as to the present rapid denudation going on in our peat bogs. Here is an area on the confines of the European plateau, exposed to Atlantic conditions and therefore having a moderate temperature, a heavy rainfall, and a moist climate—all conditions that are favourable for the growth of peat. In this area we find peat covering the floors of the valleys and the hillsides to a considerable depth, yet at the present time the peat is wasting away much faster than it is being formed. A traverse taken across the island from Barvas to Monung (the solitary hill rising to 800 feet in the north of the island), and from Monung to Stornoway, shows that for the greater part of the way the peat is cut up into a system of vegetation-covered ridges or banks separated by channels about 4 feet broad and 3 to 4 feet deep. Further, the wastage is, as we should expect, more noticeable on rising ground and hillsides, than on the levels, and is more marked as the eastern seaboard of the island is approached than on the west. Although this feature could be explained in some particular mosses by the raising of the surface, due to the activity of the peat-forming plants, the raised bog permitting freer drainage and thus paving the way for the succession of less actively peat-forming plants, such as the heather and hill-pasture associations, yet the feature is so universally present on all types of peat-bogs, on hill-tops, hill-slopes, and in valleys both in England, Scotland, and Ireland, that the ultimate cause must be sought beyond any such local and episodal events such as I have suggested. It is true that the present denuded condition of the peat is due to a change of vegetation, but the general replacement of Sphagnum associations and marsh vegetation by Calluna associations must be due to some cause operating over the whole of Britain, such as a general decrease in the humidity of the climate.

The general vegetation of the peat mosses shows a close resemblance to those on the N.W. districts of the mainland. Calluna is fairly abundant, mixed with *Scirpus cæspitosus*, *Rhacomitrium lanuginosum*, stunted *Vaccinium Myrtillus*, *Potentilla reptans*, *Erica Tetralix*, *Narthecium ossifragum*.

Sections were made in three different areas in the Lews :—

(*a*) In the centre and east of the island, to the S. and S.W. of Monung.
(*b*) South of Barvas, and also in the basin of the river Bragor.
(*c*) Submerged peat in Sandwick Bay, near Stornoway.

(*a*) *Peat Mosses South and South-West of Monung.*—These lie at a general elevation of 200–400 feet, and form gently undulating moorland in the drainage system of the Gress river. The area contains many small lochs, some of which occupy hollows in the peat.

In some places the remains of an arctic type of vegetation occurs at the base of the

peat, overlaid by birch, and in other places the birch itself occurs at the base of the peat, the older beds being wanting. Peat-formation would hardly begin simultaneously over so large an area as this, and we should expect to find some areas dating back farther than others. Details of two sections will serve to illustrate this point and to give the general sequence over this area :—

SECTION I. :—

| Characteristic Plants. | Accompanying Plants. |
|---|---|
| 1. *Scirpus cæspitosus.* | 1. Sphagnum. |
| 2. *Betula alba.* | 2. *Corylus Avellana.* |
| | *Alnus glutinosa.* |
| 3. *Erica cinera.* | 3. *Empetrum nigrum* (traces). |
| | *Eriophorum vaginatum* (scarce). |

Fine sand and rock.

SECTION II. :—

| Characteristic Plants. | Accompanying Plants. |
|---|---|
| 1. *Scirpus cæspitosus.* | 1. Sphagnum. |
| 2. *Calluna vulgaris.* | 2. ... |
| 3. Sphagnum. | 3. *Scirpus cæspitosus.* |
| 4. *Betula alba.* | 4. *Scirpus cæspitosus.* |
| 5. *Salix Arbuscula.* | 5. *Empetrum nigrum*, L. |
| | *Viola palustris.* |
| | *Carex sp.* |

The younger layers of peat resemble those in Skye, but the basal beds of *Salix Arbuscula*, Empetrum and Carices, carry the history a stage further back. Section II. shows the more general sequence, where a thick bed of creeping willow occurs at the base of the peat. This type of vegetation does not now form a continuous sheet in any of the Outer Hebrides, or at similar altitudes anywhere in Britain, being confined to mountainous regions. The *Betula alba* zone consists of fairly large trees, mixed in some places with *Corylus Avellana* and *Alnus glutinosa*. The persistence of this zone in nearly all the sections, combined with other features to be described later, suggests that it represents the lower forest, and this correlation is supported by evidence from Shetland. The upper layers of peat in this district contain no trace of forest, and in this respect they agree with the mosses in Skye and N. Uist.

(*b*) *Peat South of Barvas and the Bragor River Basin.*—The peat along the west coast has been much dug for fuel by the inhabitants of the numerous crofting villages. In some places the peat runs almost to the coast, in others there is a narrow fringe of poorly-cultivated ground a mile or so in width, protected from the sea in the neighbourhood of Barvas by extensive sand-dunes. Round the crofting villages of Barvas, Arnol, and Bragor, the peat has been entirely carried away for fuel, laying bare the gneiss, on which little or no vegetation manages to find a hold. Over other large areas the upper layers of peat have been removed, leaving a waste of crumbling black peat which does not support any vegetation. Probably all the cultivated areas have originally been covered with peat; as the turbaries are exhausted and the underlying rock reached, a

poor crop of oats and barley is grown in unfenced patches on those parts where a thin wash of sand and clay is present.

Away from the villages the moors are as yet untouched, and this is the case over the whole of the upper part of the Bragor basin.

Whilst the general sequence corresponds with that recorded from the Gress river basin, the basal beds are thicker and give more information concerning the conditions under which the peat began to form.

The general sequence found over this area is as follows :—

| Characteristic Plants. | Accompanying Plants. |
|---|---|
| 1. *Scirpus cæspitosus.* | 1. Sphagnum, *Calluna vulgaris* (generally scarce, but more plentiful near the present surface of the peat). |
| 2. *Eriophorum vaginatum.* | 2. *Calluna vulgaris.*<br>*Rhacomitrium lanuginosum.*<br>*Polytrichum sp.*, Sphagnum. |
| 3. *Betula alba.* | 3. *Corylus Avellana.* |
| 4. *Eriophorum vaginatum.* | 4. ... |
| 5. *Salix Arbuscula.* | 5. *Empetrum nigrum* (scarce).<br>*Betula nana, Potentilla Comarum, Viola palustris.* |
| 6. *Empetrum nigrum.* | 6. *Potentilla Comarum*, Sphagnum. |
| 7. Structureless peat with seeds of *Potentilla Comarum, Menyanthes trifoliata, Viola palustris, Potamogeton prælongus, Phragmites communis.* | 7. ... |
| Sand and peaty clay. | |
| Rock. | |

The fifth and sixth beds are very like the basal beds found in the Highland districts. Such a vegetation must have grown under sub-arctic conditions after the ice had left this area. It is interesting to find that the seeds of aquatic plants occur in a bed distinct from and below this. Beds formed of aquatic plants below the arctic vegetation frequently occur in other districts, such as Cape Wrath and Shetland, but they are not continuous like the upper layers of peat, but appear in one section and are absent in another only a few hundred yards away. Such beds must represent the vegetation growing in small marshy pools and near springs after the retreat of the ice, when the drier portions of the moorland were clothed with creeping willows, Empetrum, dwarf birch and other arctic plants. It is noteworthy that such occasional beds of aquatic vegetation do not appear in the hilltop and hillside peat such as the Spey-Findhorn and Findhorn-Nairn watersheds (3). In those localities the topography was unsuited for the formation of such marshy pools, and the moorland appeared to be of a distinctly drier type than in the low-lying districts.

The lower forest consists of a thick bed of birch, and generally exhibits features which tend to show that rapid denudation was going on during its formation. The peat in this bed is much decomposed ; the wood is frequently badly preserved, and sometimes little but the bark remains. Where exposed in the banks of streams, the bed is often seen to consist of birch bark closely pressed together without any intervening

peat. Such features have been noted in the forest beds of other districts, and are discussed later in describing the geographical distribution of the strata.

The upper forest is again absent in the basin of the Bragor river, thick beds of Scirpus and Eriophorum peat lying at that horizon instead of *Pinus sylvestris*.

(*c*) *Submerged Peat in Sandwick Bay, near Stornoway.*—A deposit of peaty clay underlaid by true peat occurs under mean high-water mark in Sandwick Bay to the east of Stornoway. The deposit extends some distance along the beach, but it is impossible to say how far it extends in a seaward direction. Whilst I was in the Lews, the tides were not low enough to permit of sections being cut, but, owing to the kindness of Mr D. Mackenzie of Stornoway, I received samples of all the layers from the surface to the underlying rock, and an account of the sequence and thickness of the beds. The surface lies about 6 or 7 feet under mean high-water mark, and the total depth of the

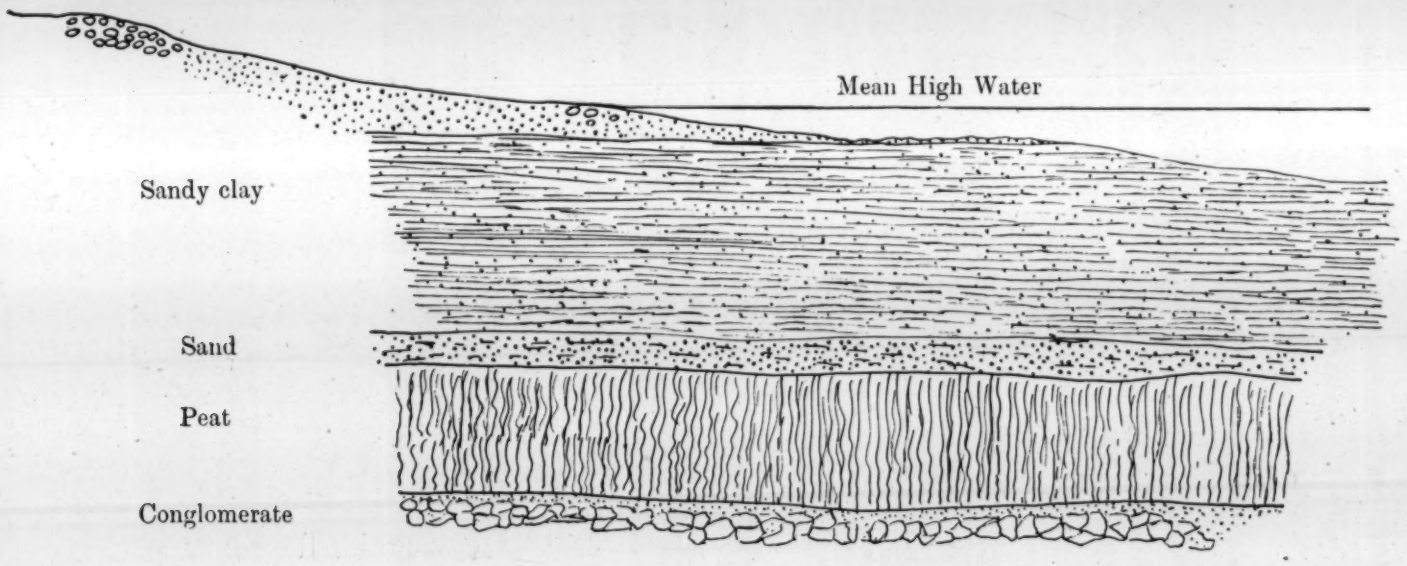


Fig. 1.—Submerged peat, Sandwick Bay. Lewis. (Vertical scale $\frac{1}{8}$ in. = 1 ft.)

deposit is 4 feet 6 inches, underlaid by conglomerate. The position of the several beds is illustrated in fig. 1.

The peat at the base of the section is dry, hard, and shows but little structure. It apparently consists chiefly of the debris of birch bark and the epidermis of *Phragmites communis* rhizomes. The material is quite free from silt, and appears to have formed an old land surface, and the peat is certainly not the accumulation of a bog, but represents a forest bed, and it is clear from this that a depression of at least 12 feet has taken place since the Lower Forestian. The sand immediately overlying the peat contains many seeds of *Zostera marina*, and some traces of Sphagnum.

## 4. The Mainland of Shetland.

(Ordnance Survey—sheets 127, 128).—The Shetland Islands might be expected to yield results of some value owing to their separation from the mainland by a

wide sea, which possibly has not been bridged in post-glacial times, their northern position, the evidence of their heavy glaciation, and the fact that there are no lofty hills on the mainland which would long nourish glaciers during the later stages of the glacial period.

Two districts were selected for examination :—

(*a*) Walls-Sandness district on the west coast of the mainland.

(*b*) Part of the ridge running N. and S. along the centre of the mainland north of Weisdale Voe.

(*a*) *The Walls-Sandness district* is a broad peninsula of undulating moorland on the west coast. The highest ground is reached in Sandness Hill (817 feet) and Stourborough Hill (567 feet), elsewhere the moorland mostly lies between 200 and 300 feet above sea-level.

Most of this peninsula is formed of sandstone and flags, giving a rounded aspect to the hills and in striking contrast to the gneissose and quartzite rocks farther east, where the hills are broken in outline and covered with dry Calluna moor. The vegetation of the sandstones and flags where the peat is thick is composed of *Scirpus cæspitosus*, *Eriophorum vaginatum*, stunted *Calluna vulgaris*, *Rhacomitrium lanuginosum*.

The peat appears to be rapidly wasting away over the whole of the mainland, and this is particularly marked on the hills in the Walls-Sandness region.

Sections will first be described from the long valley running east and west between Sandness Hill and Stourborough Hill and drained by the Burn of Dale, where the peat is much channelled, the ridges between the channels being covered with *Scirpus cæspitosus*, mounds of *Rhacomitrium lanuginosum*, stunted Calluna.

The general sequence found over this area is as follows :—

| Characteristic Plants. | Accompanying Plants. |
|---|---|
| 1. *Scirpus cæspitosus.* | 1. Sphagnum, Calluna (scarce). |
| 2. *Eriophorum vaginatum.* | 2. ... |
| 3. Dense light-coloured structureless peat crowded with the stems of Calluna. | 3. ... |
| 4. *Salix Arbuscula.* | 4. *Empetrum nigrum*, *Betula nana*, *Erica Tetralix.* |
| 5. *Betula alba.* | 5. *Corylus Avellana.* |
| 6. Sphagnum and *Eriophorum vaginatum.* | 6. ... |
| 7. *Salix reticulata*, *S. herbacea.* | 7. *Betula nana.* |
| 8. *Potamogeton pectinatus.* | 8. *Menyanthes trifoliata*, *Viola palustris*, *Ranunculus repens*, *Equisetum sp.* |
| Sand and rock. | |

There are certain interesting features in this sequence which merit more detailed description. The basal layer contains the remains of an aquatic vegetation, and although many of the plants have a wide range, all of them occur within the Arctic Circle at the present time. The relation of these aquatic plants to the overlying arctic plants is very similar to the aquatic vegetation underlying the arctic bed of Cape Wrath district already

described, although the basal arctic plant beds in the two districts are not contemporaneous.

The lowest arctic bed in Shetland contains the remains of distinctly arctic-alpine plants, and there can be no doubt that this bed was formed under cold conditions soon after the country had been glaciated.

It is at first very difficult to say whether the basal aquatic vegetation belongs to the same stage as the immediately overlying arctic plants, but the fact that the aquatic plants were only found in a few sections renders it probable that they represent small

FIG. 2.—Diagram showing the general sequence of strata in the Shetland Islands.

marshy pools which were scattered over the tundra, and therefore actually contemporaneous with the lower layers of the creeping willow elsewhere in the districts. It is true that such evidence is not conclusive, as the oldest layers of the peat are frequently missing in one part of a district and present in another part of the same district, owing to the peat having begun to grow earlier in one place than in another. Still, there is one feature which makes it extremely probable that the basal aquatic vegetation is really contemporaneous with the arctic bed, and that is the fact that *Salix reticulata* leaves (not the stems) are occasionally present in the aquatic zone. Very frequently the *Salix reticulata* bed rests in small hollows in the floor of the moss as shown in fig. 2, in some cases with aquatic plants below, in other cases without. It frequently happens

that the peat bluffs along stream sides show a band of peat formed from aquatic plants lying below the first arctic bed, either marking the position of a large pool or a former stream channel whose margin must have been fringed with Menyanthes and Potamogeton whilst the surrounding moorland was covered with willow and dwarf birch.

The arctic bed is overlaid first by 14 inches of Sphagnum and Eriophorum remains, and then by a thick bed of *Betula alba* and *Corylus Avellana*. The trees are large, and represent what must have been a forest growing over the remains of the primitive arctic vegetation.

But of still greater interest is the fact that above the forest remains the peat shows a return to arctic conditions by the occurrence of *Salix reticulata*, *Salix Arbuscula*, *Empetrum nigrum*, and *Betula nana*, in a perfectly distinct bed lying over the birch forest. This is the same sequence as I found in the Southern Uplands of Scotland, where an arctic plant bed overlaid the birch forest. There can, I think, be no doubt that the intercalated arctic bed above the birch forest in Shetland represents the same epoch as the intercalated arctic bed above birch forest in the Southern Uplands.

A distinct change of climatic conditions is necessary to produce a transition from moorland and forest vegetation to moorland covered with creeping willow and other arctic plants; and further, such climatic conditions must have operated over large areas. If that be so, the arctic zones in the peat are true horizons, and therefore a trustworthy guide to the comparative age of the beds lying below and above them.

The sections here contain two arctic beds; the Merrick-Kells district and Tweedsmuir contain only one. But the intercalated arctic bed above the birch forest is present in all, and I have little doubt that extended search would yield the basal arctic bed in the Southern Uplands. Indeed, it is quite certain that the absence of the basal arctic plants from districts in the south of Scotland is due to the imperfection of the record in the places examined, for we may be sure that a forest of birch, hazel, alder, with accompanying temperate plants, did not immediately follow the retreating ice.

As the birch forest in Shetland occurs below the intercalated arctic plants, it clearly belongs to the lower forest period, and is contemporaneous with the birch of the districts in the south of Scotland.

The lower forest bed is the only evidence of woodland conditions met with in the peat of Shetland, for, instead of the intercalated arctic plant bed being overlaid with the remains of the upper forest as in the south of Scotland, it is covered with a thick bed of dense structureless peat crowded with the stems of Calluna. This stratum bears every sign of having been accumulated under conditions which were not favourable for the rapid growth of peat. The Calluna stems are much shrunken, and frequently the interior of the stems has disappeared, only leaving the epidermis. Further, the peat itself is similar to the black crumbly peat now met with on the sides of old peat-hags, save that pressure and age have consolidated it into a hard mass. As this layer is traced along the banks of streams it is found to be of unequal thickness; carefully examined, it closely resembles the appearance of buried peat-hags. From an examina-

tion of many miles of this bed in the Sandness-Walls region I have no hesitation in saying that it marks a period of denudation during which the surface of the bed became wasted and channelled into peat-hags like those met with on the present surface of the peat.

After this, the plant remains show that the peat has formed uninterruptedly under moorland or peat bog conditions down to the present time. Some of the sections taken in the Burn of Dale showed minor variations from the sequence just described. In places the birch forest rests on the glacial deposits without any arctic plants below, thus giving the same general sequence as the Southern Uplands. It is interesting to note that in such cases the birch is larger than where it is underlaid by peat, conditions having been more favourable for growth on the glacial clays and sands than on the peat.

Other sections show that the intercalated arctic plants are not always present, as, in one or two sections, Eriophorum and Empetrum occur at this horizon instead of dwarf willow.

Two sections taken at the bottom of the dale and close by the burn showed the following sequence :—

| Characteristic Plants. | Accompanying Plants. |
|---|---|
| 1. *Scirpus cæspitosus.* | 1. ... |
| 2. *Calluna vulgaris.* | 2. *Eriophorum vaginatum.* |
| 3. Diatomaceous earth. | 3. ... |
| 4. *Betula nana.* | 4. *Empetrum nigrum.* |
| 5. *Betula alba.* | 5. ... |
| 6. Diatomaceous earth. | 6. ... |
| 7. *Salix herbacea.*<br>*S. herbacea* × *Lapponum* (?)<br>*S. reticulata.* | 7. *Betula nana.* |
| 8. *Potamogeton pectinatus.* | 8. *Carex ampullacea, Menyanthes trifoliata, Ranunculus repens, Equisetum sp., Viola palustris.* |

Whilst the three horizons are still well represented here (beds 7, 5, 4), a band of diatomaceous earth occurs above each arctic bed.

During the formation of this earth the place must have been occupied by a small lake, and it is interesting to notice that when this was the case, peat-bog plants were dominant elsewhere—as beds of Eriophorum and Sphagnum occur at this level in other sections.

A number of sections were taken round the north and south sides of Stourborough Hill and Sandness Hill. In these sections the intercalated arctic bed was even better developed than in the floor of the Burn of Dale, but the basal arctic bed was generally absent, and the lower forest rested directly upon glacial deposits on the Old Red Sandstone.

Sections taken farther west on Simli Field and Blonk Field showed that the lower forest stretched almost up to the edge of the cliffs, 200 or 300 feet above sea-level. Such a discovery is certainly surprising, as trees will not grow even in the most sheltered positions at the present time. In fact, it is even more surprising to find the

ancient birch forest in this position than to find the remains of the upper forest far above modern tree limits at 3000 feet on the Grampian Mountains.

During the examination of this region several sections were taken on the banks of Sma Lochs, S.E. of Stourborough Hill—a series of lochs of very irregular outline situated at 200 feet above sea-level. The water apparently occupies a hollow in the peat, as far as can be seen from the banks. Sections were made along the north side of the lochs. Here the banks are formed of peat which at the margin reaches a depth of 10 feet below water-level.

The following succession of strata was observed :—

| Characteristic Plants. | Accompanying Plants. |
|---|---|
| 1. *Eriophorum vaginatum.* | 1. Sphagnum, *Scirpus cæspitosus.* |
| 2. *Calluna vulgaris.* | 2. *Erica Tetralix.* |
| 3. *Betula nana.* | 3. ... |
| 4. *Betula alba.* | 4. ... |
| 5. Structureless peat with clay. | 5. ... |
| 6. *Salix Arbuscula.* | 6. *Empetrum nigrum.* |

Stone pavement.

Whilst the general succession of vegetation is similar to that already described it is remarkable to find the greater depth of peat below water-level. The sequence and relation of the beds to the water-level in the loch is shown in fig. 3. In the absence of a boat upon the loch it was impossible to take borings to see how far the peat extends under the loch, but the horizontal strata of dwarf willow, peaty clay, birch forest, and arctic birch which lie below water-level, and stretch at least some distance under the loch, must once have been exposed. A case like this shows a complete reversal of peat formation, and it is difficult to see how such a comparatively large loch could be formed in this way. It might be pointed out that the water-level was rather below than above the average height, as the loch was examined at the beginning of September after a dry summer. There is no outlet to these lochs, so that the hollow in the peat cannot be accounted for by the scour of a large stream. Such basins in the peat, occupied by small lochs, are by no means uncommon; I have observed many examples in the hilly districts of Scotland and on the Pennine Chain in England, but the present example is of interest on account of the peat upon which the loch rests, containing, first an arctic flora and then a buried forest, thus showing that extensive and prolonged changes have occurred during the peat growth.

(*b*) *The Ridge in the Centre of the Mainland to the North of Weisdale Voe.*—From Weisdale Voe to Dales Voe a band of limestone traverses the gneissose rocks of the centre of the mainland for a distance of 12 miles N. and S., and gives rise to a range of smooth rounded hills with their longer axes all pointing N. and S. None of the hills reach 1000 feet, most of them ranging from 500 feet to 921 feet on Scalla Field.

Sections were taken on Weisdale Hill, North Mid Field, Scalla Field, Gunti Field, and Fielandringa. All these hills have a thick mantle of peat which has been furrowed

into peat-hags; indeed, so extensive and deep are the channels that on a clear day they can be well seen from a distance of 12 miles. A nearer view shows that the outline of the hills is ragged or like the edge of a saw, due to the depth of the numberless peat-hags.

The vegetation, despite the low elevation of these hills, is unlike that covering the ground at 100 or 200 feet in the Sandness-Walls district. *Rhacomitrium lanuginosum* is the dominant plant in places, and many of the hillsides are covered with Rhacomitrium moor with stunted plants of *Calluna vulgaris*, *Erica Tetralix*, *Scirpus cæspitosus*, and *Empetrum nigrum*.

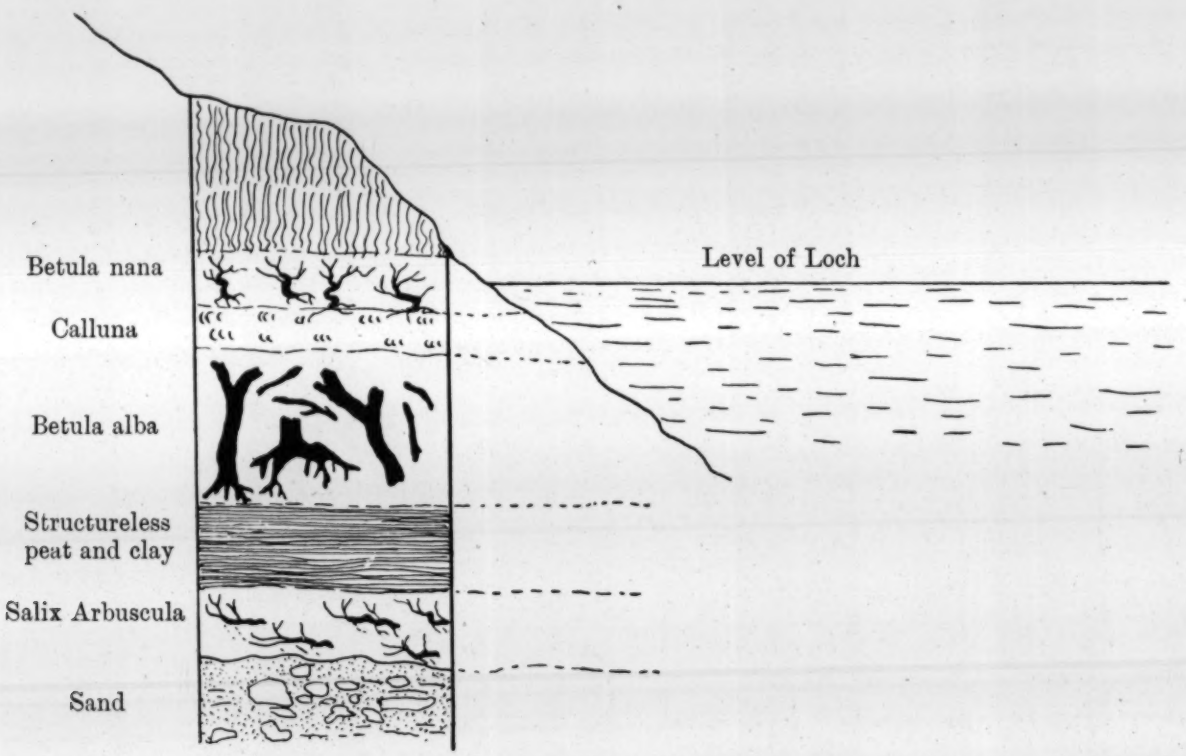


FIG. 3.—Section on the banks of Sma Loch, Shetland.

The general sequence over these hills is as follows:—

| Characteristic Plants. | Accompanying Plants. |
|---|---|
| 1. *Scirpus cæspitosus.* | 1. *Rhacomitrium lanuginosum.* *Eriophorum vaginatum.* |
| 2. *Calluna vulgaris.* | 2. ... |
| 3. *Salix sp., Arctostaphylos alpina.* | 3. *Empetrum nigrum* (abundant). |
| 4. *Calluna vulgaris.* | 4. *Eriophorum vaginatum*, Sphagnum. |
| 5. *Betula alba.* | 5. *Corylus Avellana.* |
| 6. *Empetrum nigrum.* | 6. Carices. |
| 7. *Salix reticulata.* | 7. ... |
| 8. *Potentilla Comarum.* | 8. *Salix Arbuscula* (?) |
| 9. *Carex sps.* | 9. *Hippuris vulgaris.* |

Sand and clay.

Comparing this sequence with that in the Sandness-Walls area it will be seen that whilst some of the strata contain a slightly different flora the general facies of the plant

beds remain the same. The most important point is the presence, in this area also, of the lower forest and the intercalated arctic bed above. The presence of these arctic plants above the birch forest affords a striking confirmation of the observations I made in the south of Scotland, for the fact that these beds occur in the Shetland Islands tells a still more emphatic story of widespread changes, owing to the isolation of the islands from the mainland and their now unfavourable climatic conditions for forest growth. The presence of a buried forest on the west Shetland coast below an arctic bed shows not only that arctic conditions supervened after more genial forest conditions, but that the Atlantic cyclones must have pursued an entirely different path when that forest spread over the country, for the most favourable conditions of soil and temperature would not permit forest under present climatic conditions, and indeed a more unfavourable position for tree growth could hardly be found at the present time in North-West Europe.

## Previous Work in Britain on Pleistocene Plant-bearing Deposits.

During the last thirty years much work has been done by various investigators upon plant remains in Pleistocene beds, and such work is admirably summarised in *The Origin of the British Flora*, by Clement Reid. A detailed account would be out of place here, but reference may be made to some of the districts yielding arctic plants.

It is obvious that the number of arctic horizons in Pleistocene and post-Pleistocene deposits cannot be indefinite, and therefore some of the arctic beds in peat and alluvial deposits may be contemporaneous with either one of the arctic zones in the Scottish peat mosses. For the purpose of this paper the post-glacial deposits containing arctic plants group themselves into two sets :—

(*a*) With arctic plants lying between an upper and lower temperate bed.

(*b*) With arctic plants at the base overlaid by temperate deposits.

Type (*a*) may be considered first.

At Hoxne in Suffolk four distinct superposed strata containing plant remains have been described by a Committee appointed by the British Association (6).

The sequence of the beds is as follows :—

1. Brick earth and gravel with temperate plants.
2. Black earth with arctic plants.
3. Lignite with temperate plants.
4. Clay with temperate plants.

Since the deposits fill a channel eroded through the chalky boulder clay the intercalated arctic plants must belong to late glacial times long after the general glaciation of the country.

It is sufficient to point out that the basal temperate beds contain such southern forms as *Lycopus europæus*, *Rhamnus Frangula*, *Sparganium ramosum*, *Sambucus nigra*, *Rosa canina*, whilst the arctic bed above contains *Salix polaris*, *S. herbacea*, *S. Myrsinites*, *Betula nana*, to show that there is definite evidence in the south of

England of a change from temperate to arctic conditions during the later stages of the glacial period.

Fossiliferous beds of sand and peat yielding some evidence of changes in condition have been described from Ballaugh in the Isle of Man by a Committee of the British Association (7).

In this case the evidence for a change from an arctic to a temperate flora is not so conclusive as at Hoxne. Sandy silt, containing *Salix herbacea* amongst other plants, is underlaid by loamy peat and Chara marl, from which arctic plants are absent, although most of the plants belong to species of wide distribution. The presence of *Apus glacialis* in the bed containing *Salix herbacea* certainly points to colder conditions than the present.

Numerous sections have been described in which an arctic plant bed occurs at the base of the series overlaid by deposits containing a temperate flora.

In 1894 Bennie (8) described fossiliferous beds from Hailes, near Edinburgh, the species being determined by Clement Reid. The lower beds rest directly upon the boulder clay and contain *Salix herbacea, S. polaris, S. reticulata*, together with about twenty other plants, some of which certainly do not now occur in the same regions as the arctic willows. As the basal arctic bed occurs in a lacustrine deposit it is perhaps possible that it contains fossils from slightly different periods. Be that as it may, it is certain that the arctic willows indicate a very different type of flora to the temperate bed above containing such temperate forms as *Sambucus nigra, Prunus spinosa, P. Padus, Rubus Idæus, Cratægus Oxyacantha.* These plants occur mixed with others usually considered as weeds of cultivation, such as *Chrysanthemum segetum, Æthusa Cynapium, Linum*, which suggests that the temperate bed belongs to a comparatively late period. If there is no break in continuity between the basal arctic bed and the overlying deposits containing temperate plants and weeds of cultivation, the evidence tends to show that the arctic plants belong to a period much more recent than the retreat of the ice-sheet.

Similar arctic plant beds have been described from Corstorphine (8), Faskine (9), Dronachy (10), by Bennie, and from Crianlarich by Dakyns (11), the plants from the various sections having been determined by Clement Reid.

Numerous other examples might be quoted from the lists given by Reid (11), but enough has been said to show that arctic plant beds are of wide occurrence in Britain. The arctic plants of Hailes, Corstorphine, Dronachy and Crianlarich apparently belong to the same stage, and the presence of *Salix polaris* in these deposits in the lowlands of Scotland suggests that they can hardly be younger than the first arctic bed underlying the lower forest in the peat mosses.

The section at Hoxne, where an arctic bed overlies a deposit containing temperate plants, gives the same sequence as the south of Scotland and Shetland peat where the lower forest is overlaid by an arctic zone, though the fact that the Hoxne deposits rest upon the chalky boulder clay and the Southern Upland mosses upon morainic material of a later stage makes it probable that the Hoxne temperate bed is older than the Lower

Forestian. If that be so, the arctic bed at Hoxne might still be contemporaneous with the first arctic bed of the peat mosses.

There can be little doubt that the lower bed at Hoxne represents a warm interglacial stage, showing a very different set of conditions from the beds above containing *Salix polaris* and other arctic plants, and the events which would produce such a total change in the flora in the south of England must have been widespread. The suggestion made by LAMPLUGH (12) that the arctic flora might have lingered on and re-invaded the area formerly occupied by a temperate flora without any widespread change in conditions, is surely due to a misconception of the present distribution of these plants.

It is quite certain that *Salix polaris*, *S. herbacea*, *S. Myrsinites*, *Betula nana*, and such temperate plants as *Rhamnus Frangula*, *Rubus Idæus*, *Rosa canina*, *Sambucus nigra*, *Corylus Avellana*, *Taxus baccata*, did not grow at the same time over the lowlands of the south of England. Whether the precipitation during the deposition of the arctic bed was great enough to produce glaciation on elevated ground in the north of England and Scotland the plant deposits do not tell us, but we may be certain that an arctic climate prevailed at that time. If then, from its position upon the chalky boulder clay, the Hoxne temperate bed is older than the Lower Forestian in the peat mosses, it carries the alternation of temperate and arctic phases to a still earlier stage—though a stage which all will agree is later than the last ice-sheet. It is true that evidence of actual glaciation can only be given by glacial deposits, but changes of temperature must be reflected in fossiliferous deposits.

A large amount of work has been done on the Continent since the first discovery by NATHORST in 1870 of the remains of an arctic flora in fresh-water clays near Alnarp in Sweden * (13). A great number of observations on such plant beds have been made since then, not only by NATHORST, but by other observers in Sweden, Norway, Denmark, Germany, and in Switzerland. The importance of the study of such stratified deposits before we can understand the climatic fluctuations of the Pleistocene and the modern distribution and character of the flora, has been fully recognised in those countries. In Canada and the United States hardly any work on the succession of the flora has been attempted, although those countries contain extensive peat deposits. The Bulletins of the U.S. Geological Survey contain many records of peat deposits which from their position in relation to the drifts and their geographical situation promise much interesting material towards the history of changes in the distribution of the flora.

If the birch zone of Sweden is contemporaneous with the Lower Forestian of Scotland, as I suggested in 1906 (3), it is interesting to notice that the oldest forest zone in both countries consists of birch. But it is impossible to say whether the spruce and oak zones recorded from Sweden represent all the peat lying between the

* I should have made it clear in Part II. that the first discovery of Arctic plant beds in Sweden was made in 1870, and was entirely due to the investigations of NATHORST. These investigations were of course made in Sweden and not in Norway, as was inadvertently stated in Part II. A sketch of the investigations made up to 1891 is given by NATHORST in the paper referred to above (13).

Lower and Upper Forestian, or the lower zone of trees in the Upper Forestian of the Highlands.

In any case, the first arctic bed of Shetland and the Outer Hebrides must belong to the same horizon as the arctic bed first described by NATHORST from the base of the Swedish peat mosses.

## THE GEOGRAPHICAL DISTRIBUTION OF THE ZONES IN THE PEAT.

As about twenty-four districts have been investigated during the last three years between the south of Scotland and the Shetland Islands, Aberdeenshire and the Outer Hebrides, the geographical distribution of the principal zones and the variations shown by the same horizons in different districts may now be briefly indicated.

The following stages are represented in the peat of the south of Scotland, the Highlands and the Hebrides :—

1. Recent peat.
2. Forest.
3. Peat bog plants with arctic plants.
4. Forest.
5. Peat bog plants.
6. Arctic plant bed.
7. Peat bog plants.
8. Forest.
9. Arctic plant bed.

It is obvious that some terminology must be used in discussing the distribution of these beds, and it will be simpler to provisionally name them for the purpose of description and then point out the possible correlation of these strata with stages in the glacial period for which a terminology already exists.

The following names will then be adopted :—

| | |
|---|---|
| 1. Recent peat. | |
| 2. Forest bed. | Upper Forestian. |
| 3. Peat bog plants with Arctic plants. | Upper Forestian. |
| 4. Forest bed. | Upper Forestian. |
| 5. Peat bog plants. | Upper Peat Bog. |
| 6. Arctic plant bed. | Second Arctic Bed. |
| 7. Peat bog plants. | Lower Peat Bog. |
| 8. Forest bed. | Lower Forestian. |
| 9. Arctic plant bed. | First Arctic Bed. |

Strata 2, 3, 4 are all classified as "Upper Forestian," for reasons which will be given later.

*The First Arctic Bed.*—This bed has, so far, only been met with in the Outer Hebrides and the Shetland Islands. Occurring at the base of all the beds, and resting

upon the glacial deposits, it represents the arctic flora covering the peat area before the growth of the overlying temperate Lower Forest. The flora is best preserved in Shetland, where the remains of *Salix reticulata*, *S. herbacea* × *Lapponum* (?), *Betula nana*, form a layer about 1 foot in thickness.

Such creeping Salices occur about 2000 feet on the summits of many of the Highland mountains at the present time, but the conditions in Shetland must then have been entirely different to those which now obtain on our mountain summits; for below the bed of creeping willow occur many aquatic plants such as *Carex ampullacea*, *Menyanthes trifoliata*, *Ranunculus repens*, *Equisetum sps.*, *Viola palustris*, *Potamogeton pectinatus*. These plants do not occur on the dry wind-swept summits where arctic willows now grow in Britain; the flora rather suggests an arctic march or tundra with many scattered pools containing an aquatic vegetation.

This bed so frequently underlying the arctic willow can hardly belong to an earlier stage in the peat history, as the leaves of *Salix reticulata* are frequently present amongst the aquatic and marsh plants, and have evidently been blown in from the surrounding moorland. The aquatic zone contains much silt, clay, and sand, whilst the bed of creeping willow is entirely free from such deposits.

After the ice retreated, the ground must have been intersected by numerous rills, streams, and pools, in which grew Equisetum, Potamogeton and Menyanthes. Muddy streams frequently covered this vegetation with fine silt and sand. The drier ground was covered with a close growth of *Salix reticulata* and other arctic-alpine plants, which, as the pools gradually became silted up, spread over these spots also. It is quite evident that the climate of that period allowed a fairly lengthy time for the flowering and ripening of the seeds of such aquatic plants. In fact, the flora indicates a wet cold climate rather than dry conditions with an arctic temperature. Either the First Arctic Bed began to form some time after the disappearance of glacial conditions, or the rise of temperature must have been very rapid during the wane of the glaciers. The richness of the flora indicates that the glacial stage, represented by this bed, was much later than the main ice sheet.

In a recent account of the development of the Scandinavian flora, GUNNAR ANDERSSON (14) records the occurrence of *Potamogeton filiformis*, *P. prælongus*, *Menyanthes trifoliata*, *Batrachium confervoides*, and other aquatic plants in the Dryas zone, and infers that the Scandinavian climate of that time was not arctic like that, for instance, of North Greenland, but rather resembled South Greenland at the present time. This conclusion is in complete agreement with the features I have found in the N.W. Highlands. The arctic stages appear to mark periods of great precipitation, and these apparently alternated with comparatively dry temperate stages.

The character of the First Arctic Bed is different in the Outer Hebrides—the only other district in which the peat is old enough to go back to this date. In Lewis, the oldest layer contains *Salix Arbuscula*, *Betula nana*, *Potentilla Comarum*, *Empetrum nigrum*, *Menyanthes trifoliata*, *Potamogeton sps.*

Some of these are plants of wide distribution from temperate to arctic regions; others, like *Betula nana* and *Salix Arbuscula*, have an entirely arctic or sub-arctic distribution and do not now occur near sea-level in Britain; but these basal beds suggest less rigorous conditions than those in the Shetlands, for bog plants of wide distribution are the most abundant; whilst in the Shetlands, *Salix reticulata* is the characteristic plant.

The plants of the First Arctic Bed must have immigrated to Scotland, either across the North Sea, or through England. The incoming flora would probably pass along the higher ground, while the valleys and lowlands were still covered with the shrinking remnants of the local ice-sheets. The evidence from the mosses in Lewis certainly suggests that the incoming arctic flora barely established itself in the extreme west of Scotland before the Lower Forest overspread the peat bogs, as the typical arctic plants represented in Shetland are either absent or poorly represented in the corresponding zone of the Hebrides.

*The Lower Forestian.*—Considerable interest attaches to the flora of this zone, owing to the absence of any arctic or sub-arctic plants, suggesting that a complete change of conditions took place between the first and second arctic beds during which the arctic flora withdrew from the peat areas.

In the Southern Uplands, Hebrides and the Shetlands, the Lower Forest is well preserved, the trees being *Betula alba*, *Corylus Avellana*, *Alnus glutinosa*. The list of accompanying plants is not large, as the peat is chiefly formed of wood debris and bark. Inferences as to temperature drawn from these trees alone are inconclusive, but certain features presented by the distribution of the forest-bed bear directly upon the general climatic conditions of that time. The presence of a buried forest extending to the western coast of Shetland points indubitably to the fact that the path of the Atlantic cyclonic systems must then have been different to that of the present day. Trees are now entirely absent from Shetland, although many attempts have been made to form plantations in sheltered spots. Planted in gardens, ash, rowan and birch grow as high as the surrounding walls, and are then stunted by the winds, so that the trees appear to be shorn off at the level of the protecting wall. If this takes place at the inland and more sheltered spots, it is still more difficult to account for the presence of the buried forest near the cliffs of the west coast, where the full force of the Atlantic gales is felt, as they succeed one another during the greater part of the year. As the mean annual temperature of the Shetlands is perhaps higher than many parts of Britain which are tree-clad, the absence of trees in these islands must be due, not to temperature, but to the force of the salt-laden winds.

The accompanying flora of the Lower Forest contains many plants of wide distribution which do not give any definite evidence with regard to temperature. The zone also contains other plants, which are not usually found accompanying arctic plant associations, such as *Ajuga reptans*, *Ranunculus lingua*, *Lychnis diurna*, *Salix purpurea*.

But the most significant fact is that none of the characteristic arctic plants of the First and Second Arctic beds are to be found in the Lower Forest Bed, though quantities of material from the south of Scotland, the Hebrides and the Shetlands, have been worked through. If it still be urged that there is no direct proof that the Lower Forest Bed was accumulated under temperate conditions, one may ask what was the reason for the disappearance of the characteristic plants of the First Arctic Bed during this period, and why should these typical arctic species again appear as the strata above the Lower Forest are reached?

The upper limit of tree growth has been used both in Britain and on the Continent as the approximate boundary between the sub-alpine and alpine floras, and it is found that a considerable difference in altitude separates the zone of natural woodland from the alpine associations.

From this, the First Arctic Bed appears to be the result of the depression of the present alpine-arctic boundary in Britain to the extent of about 2000 feet, whilst the Lower Forest represents the return of that boundary to at least its present altitude.

The chief features in the distribution of the First Arctic Bed and the Lower Forestian are shown in Plate II. The absence of these two beds from the Highland districts is remarkable. Either conditions were not favourable for peat formation in those areas during the First Arctic, the Lower Forestian, and the Lower Peat Bog period, or peat formed during those periods was subsequently removed either by glaciation or by atmospheric agencies. Further areas must be examined before it is possible to say which view is correct.

At the same time it must not be forgotten that water action frequently plays a great part in the removal of peat beds. Many cases have come under my notice in various parts of Scotland and the north of England where the older beds along a stream-side have been swept away and replaced by mounds of sand and gravel. This is illustrated in fig. 4, showing a sharp bend in the Abhuinn-a-Coire-Bhuig in Easter Ross, where all the older peat beds have been washed away and replaced with sand and gravel. This event occurred before the Upper Forestian, and most probably during the Upper Peat Bog stage. It is not, of course, suggested that the absence of the older peat beds in the Highlands can be due to water action of this character, but the example is given in order to emphasise the many occurrences which may be responsible for the absence of the older beds of peat in some districts. It is quite evident that peat formation is dependent upon many factors, such as temperature, humidity of climate, drainage, character of soil and the flora, or the peat deposits of Britain would not be so local in distribution.

No trace of *Pinus sylvestris* has been found in the Lower Forest, although it is the most characteristic tree of the Upper Forest. If native in Scotland at that time it is difficult to see why it should not occasionally have spread over the peat-covered areas, but neither in the south of Scotland nor in the Hebrides and Shetlands is any trace of it to be found.

*The Lower Peat Bog.*—This zone is present in the low-lying Wigtownshire mosses, and the other areas examined in the Southern Uplands, in Skye, the Outer Hebrides, and in the Shetlands. In the Southern Upland areas and the Shetlands it exhibits the greatest uniformity, the bulk of the peat being formed from the remains of Sphagnum, *Scirpus cæspitosus*, *Eriophorum vaginatum*, *E. angustifolium*, *Molinia cærulea*, Carices. Calluna is scarce or absent, and the peat areas at this time seem to have formed extremely wet Scirpus and Sphagnum moors, and trees appear to have been entirely absent. The peat bears every sign of having been formed under conditions eminently favourable for peat growth, and although this zone frequently attains a thickness of 5 to 7 feet it is

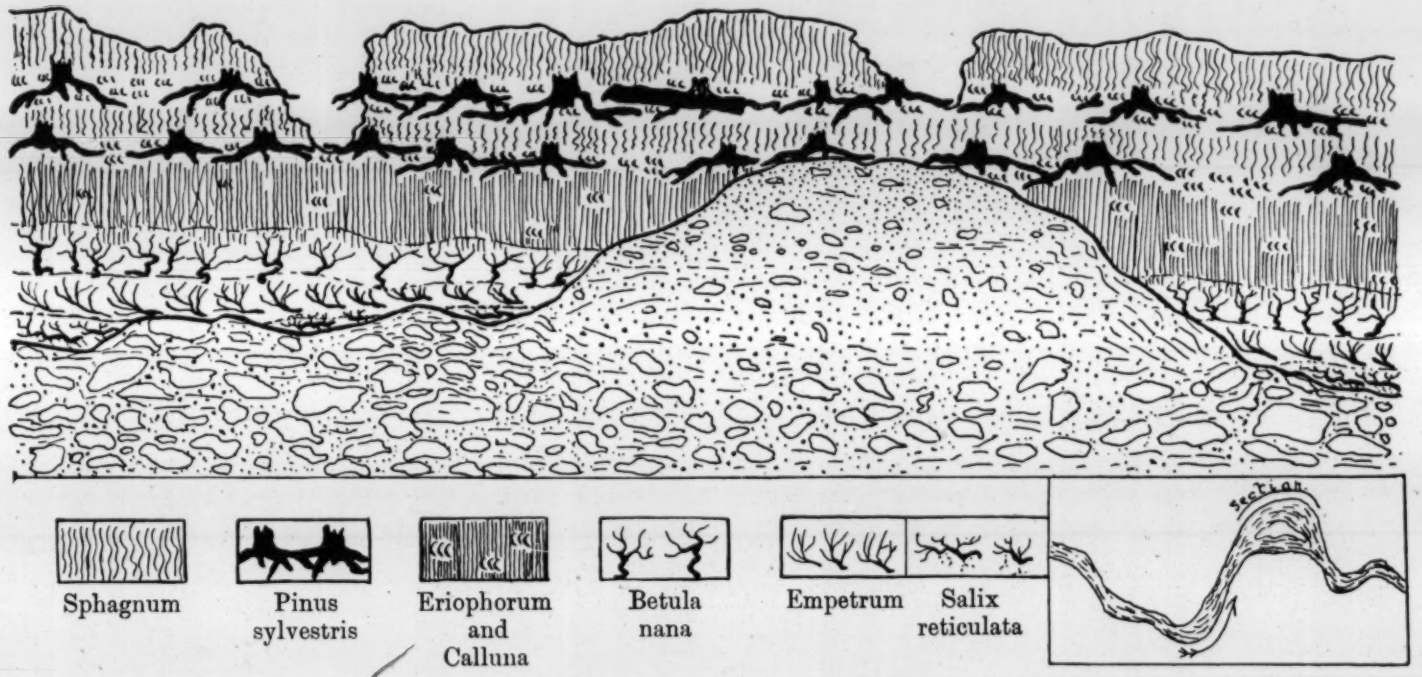


FIG. 4.—Showing the replacement of the older beds of peat by fresh-water sands and gravels at sharp bends along stream-sides. 1400 feet on the Abhuinn-a-Coire-Bhuig, Easter Ross.

probable that it was formed in less time than the First Arctic Bed, which is only 18 inches in average thickness.

In the low-lying districts of Wigtownshire, Skye, and the Uist a different type of flora overspread the peat during this stage, for the Lower Peat Bog there consists of the remains of *Phragmites communis*, *Equisetum sps.*, *Menyanthes trifoliata*. In fact, these areas must have been covered with a series of shallow lakes and swamps, possibly explained by the fact that the peat rests upon stiff clays, whilst many of the Southern Upland mosses rest upon sand and gravels. In Lewis, the Lower Peat Bog approximates more to the Southern Upland type, being composed of Sphagnum, *Eriophorum angustifolium*, *Erica Tetralix*.

A noticeable feature is the fact that the Lower Peat Bog tends to thin out as it is traced across Scotland from the south to the north. This is a phenomenon of some interest, particularly when considered in connection with the significance of the succession

of the peat strata. It is evident that these successive beds represent changes in plant distribution on a great scale, or occupying presumably considerable spaces of time. The Lower Peat Bog stage undoubtedly represents a great invasion of North Britain by swamp and bog plants which previously had their centre either in the south or east of Britain. If that be so, the arrival of this type of flora would be much later in the extreme N. of Scotland than, for instance, in the Southern Uplands. It is perhaps not without significance that in Shetland the Lower Peat Bog thins out to a bed only a few inches in thickness or a layer of diatomaceous earth. The centre of distribution of these swamp and bog associations could hardly have been in the north of Britain during the growth of the lower forest, and the farther the areas were from this centre the longer it would be before they were colonised.

*The Second Arctic Bed.*—The Lower Peat Bog is succeeded by a flora composed mainly of typical arctic plants and, as will be seen from Plate II., is represented in every district so far examined along the line A B on Plate I. from the Southern Uplands to the Shetlands. In the south of Scotland the zone contains *Salix reticulata*, *S. herbacea*, *Loiseleuria procumbens*, *Empetrum nigrum*, *Arctostaphylos alpina*; but in the Highlands and in the Shetlands *Salix reticulata*, *Betula nana*, *Empetrum nigrum*, *Salix Arbuscula*, *Erica Tetralix*. In these areas the Second Arctic Bed occurs between the Lower and the Upper Peat Bog, but in the areas which lie within the Highlands no older beds lie below this zone, and it rests directly upon sands, gravels, and clays. In such districts the bed is thicker and contains a richer flora than in the Shetlands and south of Scotland.

In the areas stretching from the Grampian mountains to Cape Wrath the peat of this bed contains *Dryas octopetala*, *Salix reticulata*, *S. herbacea*, *Arctostaphylos alpina*, *Betula nana*, *Veronica alpina*, *Lychnis alpina*, *Salix Arbuscula*, *Carex sps.*, *Equisetum sps.*, *Empetrum nigrum*, *Potentilla Comarum*, *Viola palustris*, *Menyanthes trifoliata*.

In the district near Cape Wrath these plants are frequently underlaid by a thin seam of peat a few inches in thickness, composed of the remains of aquatic or marsh vegetation, consisting of *Ranunculus repens*, *R. flammula*, *Potamogeton natans*, *P. prælongus*, *P. rufescens*, *Menyanthes trifoliata*. This seam is not continuous but appears to underlie the Salix beds in small patches and frequently in depressions of the ground, and marks the position of small swampy patches during the Second Arctic Period.

In the districts of the extreme west, along the line B C, Plate I., such as Skye, N. Uist and Lewis, the Second Arctic Bed is not recognisable, and the First Arctic Bed is but poorly represented. After the close of the Lower Forestian the general type of vegetation over these peat mosses seems to have remained very uniform, through the Lower Peat Bog, Second Arctic Stage, and the Upper Forestian to the present day. During those periods the mosses in the Hebrides must have resembled the tundra of Northern Siberia described by Sewell (15).

The observations from the Shetlands illustrate the same feature, for although the Second Arctic Bed is present, yet the Upper Forest does not seem to have spread over the peat areas. Shortly stated, the farther one passes to the edge of the Continental plateau the more uniform does the flora appear to have remained since the later stages of the glacial period. This may imply either that the climatic conditions have been more uniform in those regions, or that the successive waves of vegetation passing over the mainland did not penetrate there on account of natural barriers to immigration. The peat does not afford any direct evidence upon these points, for whilst the Second Arctic Bed was being formed on the mainland, the peat mosses of the Hebrides were covered with marsh consisting of *Phragmites communis* and Equisetum, which might well occur under cold or under temperate conditions.

*The Upper Peat Bog* is developed in all districts, and the flora is generally very similar to that of the Lower Peat Bog. In some of the Highland areas, such as the Spey-Findhorn watershed, Findhorn-Nairn watershed, Coire Bog, Cape Wrath district, Rannoch Muir, remains of small *Betula alba* shrubs occur in the lower parts of this zone. The wood is very local in occurrence, whilst the main mass of the peat is formed of *Scirpus cæspitosus*, *Eriophorum angustifolium*, *E. vaginatum*, and Sphagnum. Evidently these small clumps of shrubby birch were soon displaced, as no wood is met with above the first foot or so of the Upper Peat Bog. In the Hebrides and the lowland mosses of Wigtownshire the Upper Peat Bog is simply a continuation of the Lower Peat Bog, there being no layer of arctic plants between.

*The Upper Forest Bed.*—This zone is confined to the mainland of Scotland from the lowland mosses of Wigtownshire to the valley of the Dionard, south of the Kyle of Durness. Whilst the flora exhibits remarkable uniformity, some interesting and important modifications appear as the bed is traced northwards through Scotland. In the areas of the south of Scotland the forest consists of *Pinus sylvestris*, with the exception of some parts of Tweedsmuir, where *Betula alba* replaces pine. As soon as the Highland areas are entered the Upper Forest divides into two distinct zones separated by 1–3 feet of peat in which no wood is found. In the Spey-Findhorn, Findhorn-Nairn, Coire Bog districts, the peat between the upper and lower layers of this forest is formed from Sphagnum, but in areas examined in the Grampians and in Assynt, *Betula nana* and *Salix Arbuscula* are abundant between the two layers of forest remains. The presence of these plants in some districts, and of Sphagnum beds in others, between two layers of well-developed pine forest, is significant, and points to a decided break in forest conditions at this time. This phenomenon is too widespread to be due to local causes, for it is a constant feature in all the Highland areas examined.

*Betula alba* replaces *Pinus sylvestris* in the lower zone of the Upper Forest on the Grampians, in Assynt, and over much of the Caithness-Sutherland border; in other words, at high elevations and in the extreme north.

It is remarkable that until the Upper Forest is reached no extensive beds of Calluna

are found. The Vaccinium-Calluna association, now so constant a feature on moorlands in Scotland and England, appears to be a comparatively recent feature.

*The Peat above the Upper Forest.*—The peat of varying thickness lying above the Upper Forest presents the same features as the Lower and Upper Peat Bog. Occasional beds of Calluna or Eriophorum make their appearance, but are not continuous over large areas, and are evidently due to local causes. The general flora is of a distinctly wetter type than that characteristic of many of the peat areas of the present time, as it consists mainly of *Scirpus cæspitosus* and Sphagnum. Although this zone does not indicate any widespread changes in the distribution of the flora it shows some features of œcological interest in connection with the present denudation of the peat; these will be dealt with in another paper.

## The Relation of the Strata to the Glacial Succession.

It is evident that the peat mosses do not give any information about the chain of events during the maximum glaciation of the country, and it is immaterial whether we regard the morainic material upon which so many of the older peat mosses in the south of Scotland rest, as the deposits of the waning ice-sheet of maximum glaciation, or as the deposits of an entirely distinct glacial stage, separated from the ice-sheet by a warm inter-glacial phase. The fact remains that the First Arctic Bed contains an arctic-alpine flora which existed over wide areas near sea-level. It is of course impossible to say from the evidence of the plants whether all traces of glaciation had vanished from Britain at that time, or whether certain regions were still under ice. An entirely different flora makes its appearance in the Lower Forestian; not only are all arctic-alpine plants absent, but the flora is made up of well-grown trees and an assemblage of plants quite typical of any marshy lowland forest region in Britain at the present time.

If it be contended that the Lower Forestian is due to local changes in climate—such as variation in snowfall, direction of wind—how is it that the bed maintains its character, not only in the south of Scotland, but also in the Outer Hebrides and Shetland Islands?

If the succession of the First Arctic by the Lower Forestian, Lower Peat Bog and Second Arctic Bed were really due to local causes, widely separated districts should show different successions; while, for instance, tundra vegetation would be represented in one district the remains of a forest vegetation would occupy the same horizon in another. But this is not the case, for nothing is more striking than the continuity of the horizons. The chief points for consideration may be stated as follows;—

(*a*) *First Arctic Bed.* Lower limit of arctic-alpine vegetation depressed nearly to sea-level.

(*b*) *Lower Forestian.* Upper limit of deciduous trees raised to *at least* its present level.

(*c*) *Second Arctic Bed.* Lower limit of arctic-alpine vegetation depressed nearly to sea-level.

(*d*) *Upper Forestian.* Upper limit of trees raised to over 3000 feet above sea-level.

These changes are post-glacial in the sense that they occurred later than the last ice-sheet. It is difficult to reconcile these changes with the "gradually waning glaciation, during which there were occasional local advances of the mountain-glaciers in their glens due to temporary increase of snowfall" suggested by LAMPLUGH (12).

The beds rather indicate a definite sequence of events which took place simultaneously over the whole of Britain. Local changes of snowfall, and local retreat and advance of glaciers, almost certainly occurred during the later stages of the glacial period, but these could hardly bring about the widespread alternate depression and elevation of the limits of an arctic-alpine flora shown by the peat.

It matters little whether these stages are spoken of as local changes during the waning glaciation or are expressed as glacial and inter-glacial stages; the fact remains that the climatic fluctuations were lengthy and pronounced enough to change the distribution of the flora in the north of Britain.

As the arctic beds contain plants indicative of cold and wet conditions, the probability is that glaciation took place in elevated regions during their deposition. The Lower Forestian contains a flora indicating conditions at least as temperate as the present day, and the Upper Forestian shows an elevation of the upper limit of forest far above that of the present day.

In Sweden a similar elevation of the upper limit of forest to the extent of 1100 feet (300 m.) took place during post-glacial times, and GUNNAR ANDERSSON concludes that the arctic-alpine flora then disappeared from the lower mountain ranges. My own observations in Scotland would place the difference between the upper limit of trees during the Upper Forestian and at the present day at not much less than 2000 feet in the Highlands; in Cumberland and Westmorland at rather more. It is possible that glaciers still lingered on in many parts of the Highlands during the earlier stage of the forest periods; this would be more likely in the case of the Lower Forestian than the Upper Forestian.

The question of climate during the Pleistocene epoch has been discussed by HARMER (16) in an interesting and suggestive paper, and the conclusion is reached that a change in the direction of prevalent winds, due to different relative positions of areas of high and low barometric pressure, may account for the comparatively low temperature and high precipitation during some stages of the Pleistocene period. The observations from Shetland certainly show a difference in the direction of the prevalent winds during the Lower Forestian.

While it is difficult to reconcile the several stages in the peat with the theory of a single glaciation, the whole of the peat beds agree very closely with the scheme of classification proposed by GEIKIE (17). In that scheme the First Arctic Bed and Lower

Peat Bog would mark the gradual passage of the Mecklenburgian stage into the Lower Forestian, the Second Arctic Bed would represent the Lower Turbarian, and the Upper Forest in the peat would correspond with the Upper Forestian or Fifth inter-glacial stage.

## Summary.

All the Scottish peat mosses show a definite succession of plant remains. The oldest, in the south of Scotland and the Shetland Islands, have an arctic plant bed at the base. This is succeeded by a forest of birch, hazel, and alder containing temperate plants. A second arctic plant bed occurs above the Lower Forest and is overlaid in all

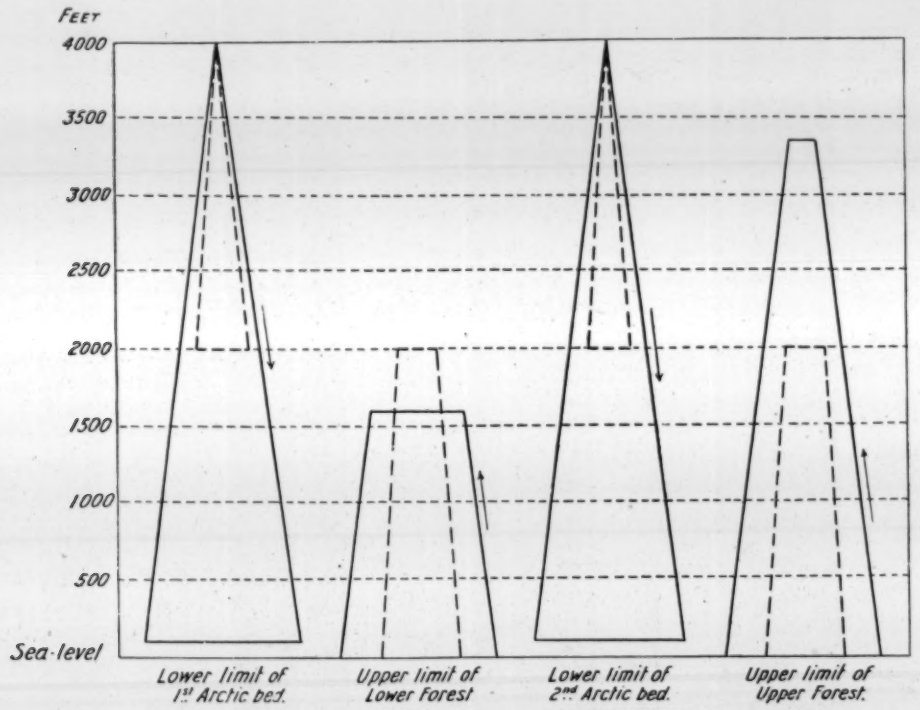


Fig. 5.—Broken lines represent the present limits of Arctic-Alpine and forest vegetation; thick lines show the limits attained by these formations during the growth of the peat.

districts (except the Hebrides, Cape Wrath, and the Shetland Islands) by an Upper Forest covered by several feet of peat-bog plants.

The altitudinal limits of these successive zones is shown in fig. 5. It will be seen that the two arctic beds descend to within about 150 feet of sea-level, whilst the Lower Forest rises to 1500 feet and the Upper Forest to close upon 3500 feet. The present lower limit of an arctic-alpine vegetation in Britain is taken as 2000 feet, and the upper limit of forest (pine and birch) as 2000 feet, although in many districts it lies considerably lower than this. The upper limit of the Lower Forest is given at 1500 feet, owing to the fact that all the beds below the second arctic zone are wanting above this altitude; but as the Lower Forest is present in many exposed situations, such as the west coast of Shetland, it is probable that the upper limit of forest lay considerably above this level.

In conclusion, I wish to express my thanks to Dr HORNE, F.R.S., for much valuable help and advice and for the use of Geological Survey maps, both published and in manuscript. My best thanks are also due to Professor GEIKIE, LL.D., D.C.L., F.R.S., for many suggestions.

The scientific expenses of this investigation have been defrayed by a grant from the Government Grant Committee of the Royal Society, London.

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## EXPLANATION OF PLATES.

PLATE I. Map of Scotland, showing the areas investigated during 1904, 1905, 1906.

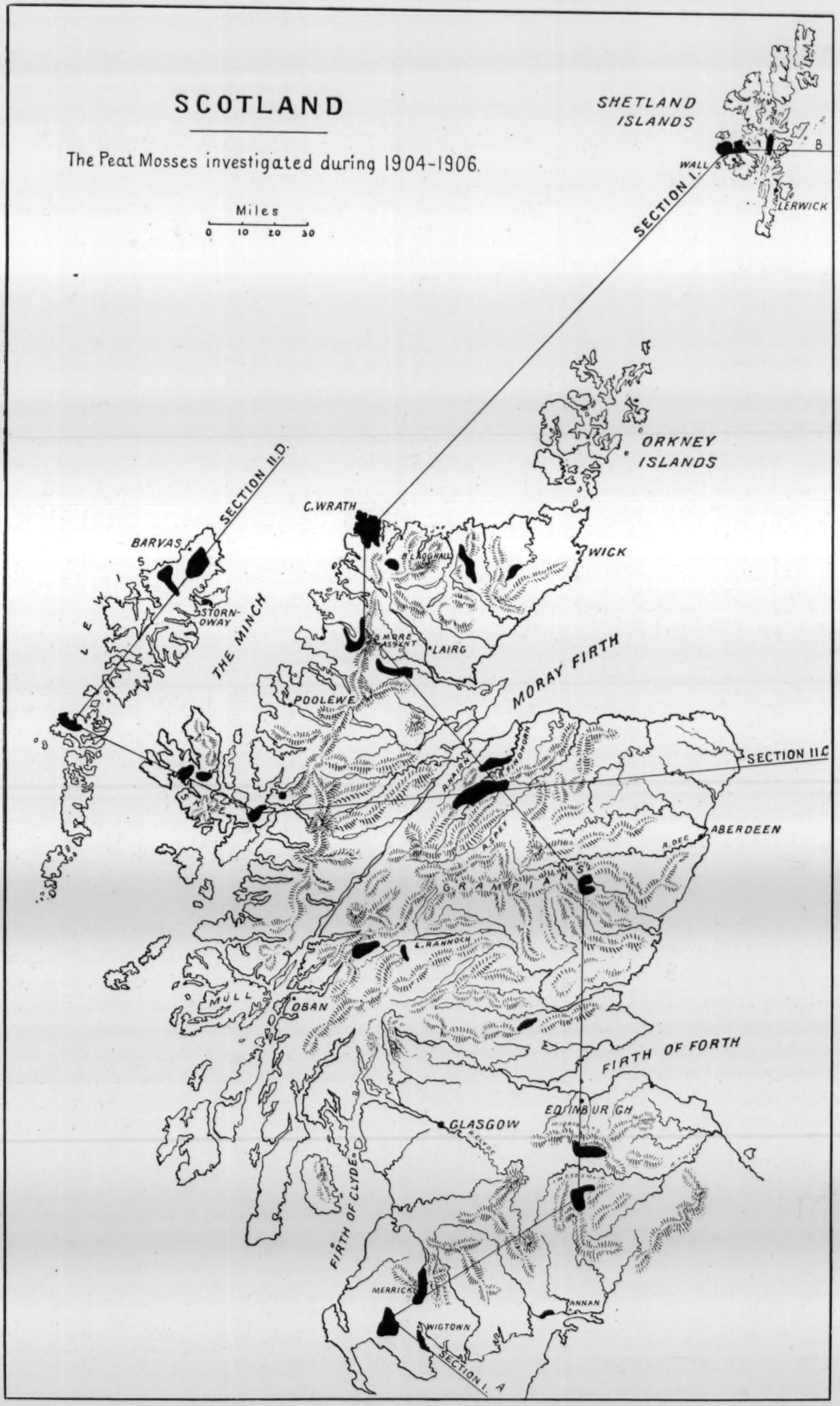
PLATE II. Sections I. and II., illustrating the sequence along the line A B, C D, respectively on Plate I.

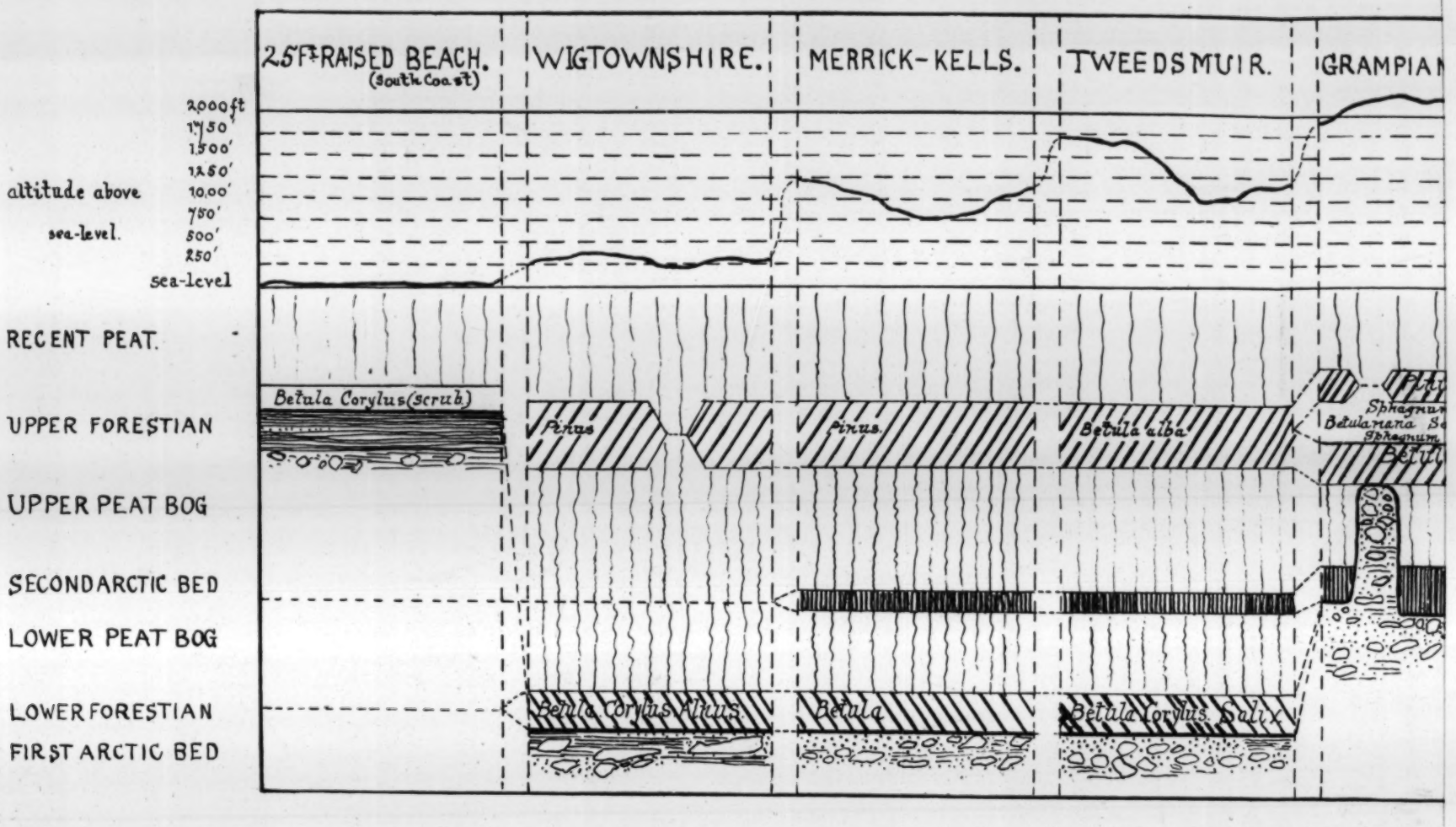
PLATE III. Plant remains from peat deposits.

Fig. 1. *Betula nana* leaves from between the two layers of upper forest, Rannoch Muir (*a b* × 8; *c* nat. size).

Fig. 2. *Salix reticulata* leaves from the first arctic bed, Shetland.
Fig. 3. *Arctostaphylos alpina* seed from the basal arctic bed, Spey-Findhorn watershed.
Fig. 4. *Ranunculus repens* achene from below the second arctic bed, Cape Wrath.
Fig. 5. *Hippuris vulgaris* seed from basal layers, Shetland.
Fig. 6. *Potentilla Comarum* achene from basal layers, Shetland.
Fig. 7. *Empetrum nigrum* seed from second arctic bed, Spey-Findhorn watershed.
Fig. 8. *Potamogeton natans* from below the first arctic bed, Shetland.
Fig. 9. *Corylus avellana* nut from the lower forest, Skye.
Fig. 10. *Alisma plantago* fruit from basal layers, Moorfoot Hills. *a*, view from above; *b*, side view.
Fig. 11. *Pinus sylvestris* cone from upper forest, Coire Bog, Easter Ross.
Fig. 12. *Salix Arbuscula* leaf from basal layers, Coire Bog, Easter Ross.
Fig. 13. *Viola palustris* seeds from basal layers, Lewis.
Fig. 14. *Menyanthes trifoliata* seed from the lower forest, Shetland.
Fig. 15. *Ajuga reptans* seed from lower forest. Tweedsmuir.

LEWIS: Plant Remains in the Scottish Peat Mosses. Part III.—PLATE I.



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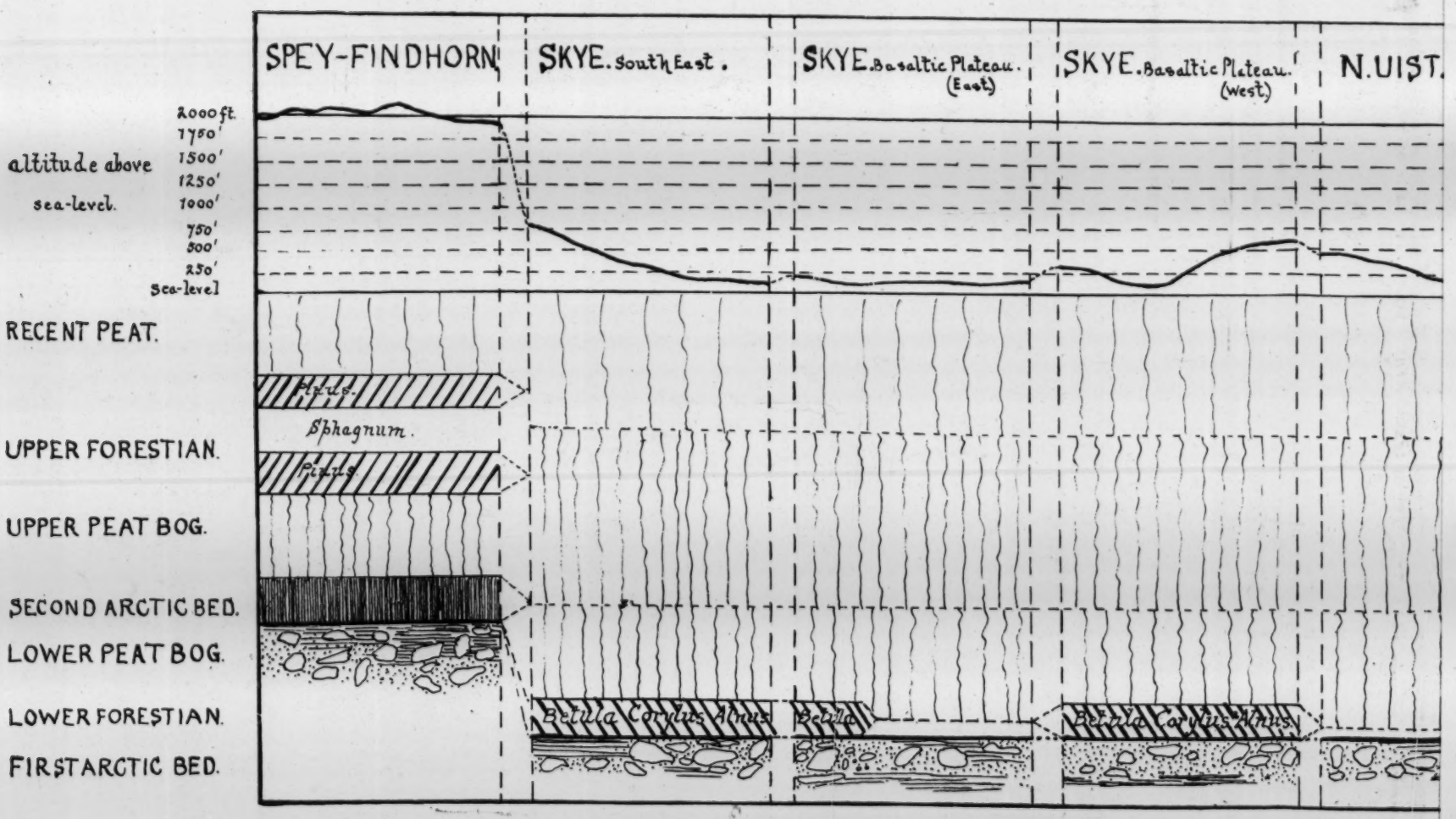


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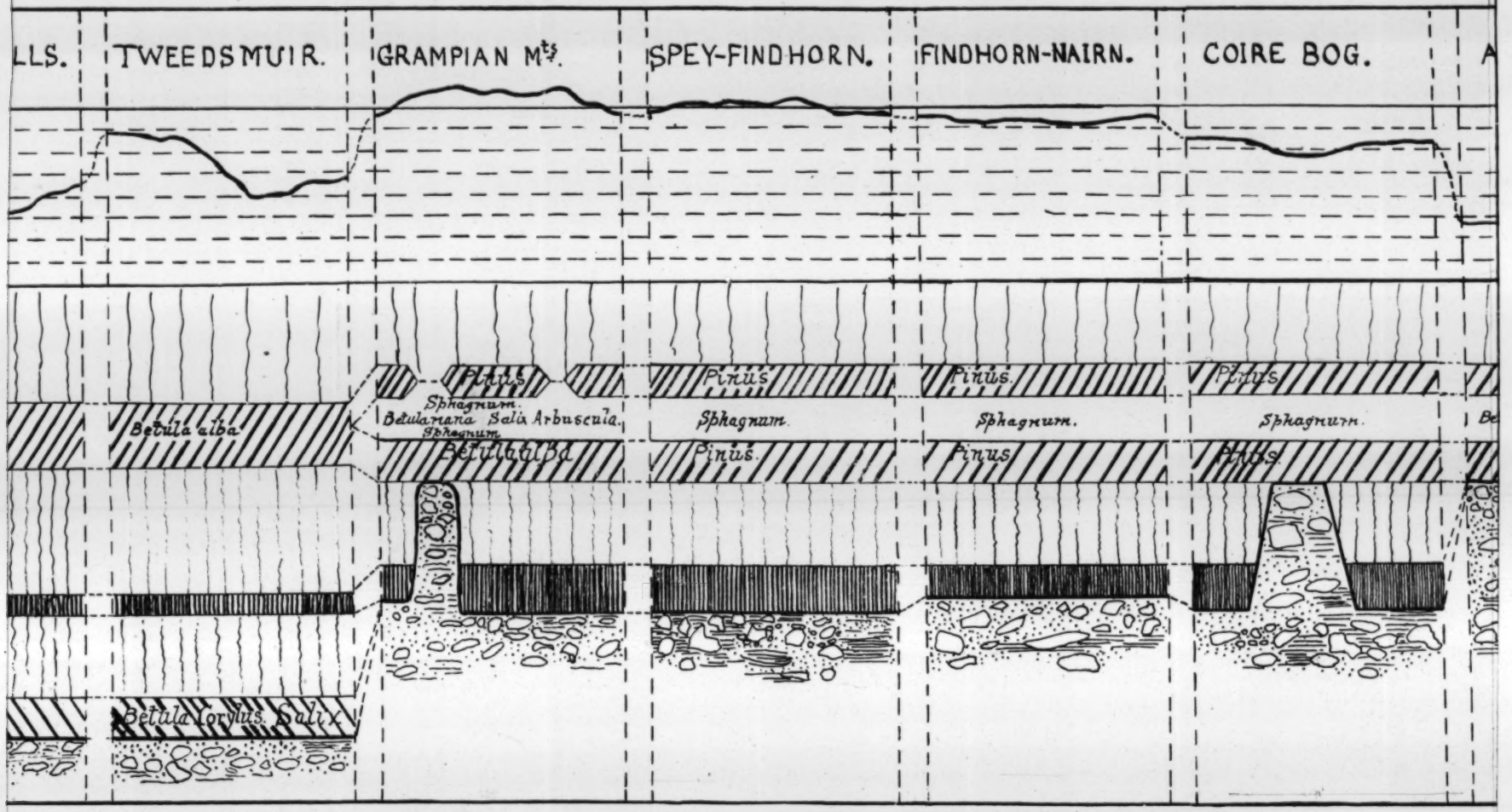
F. J. LEWIS: PLANT REMAINS IN SCOTTISH PEAT MOSSES. — PART III.

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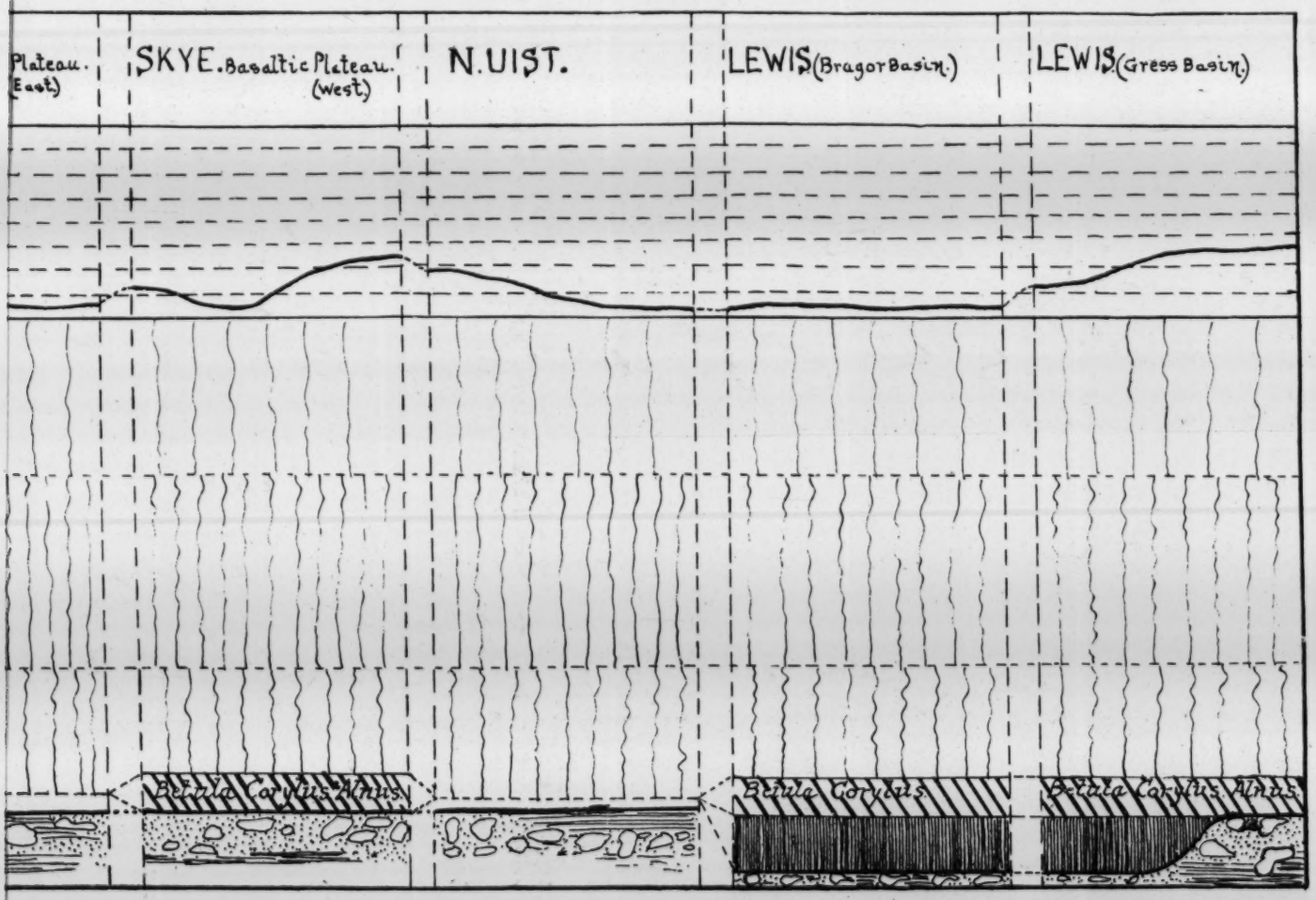



PLANTS (

Salix retic

Arctostap

Lychnis a

Sedum Rh

PLANTS O

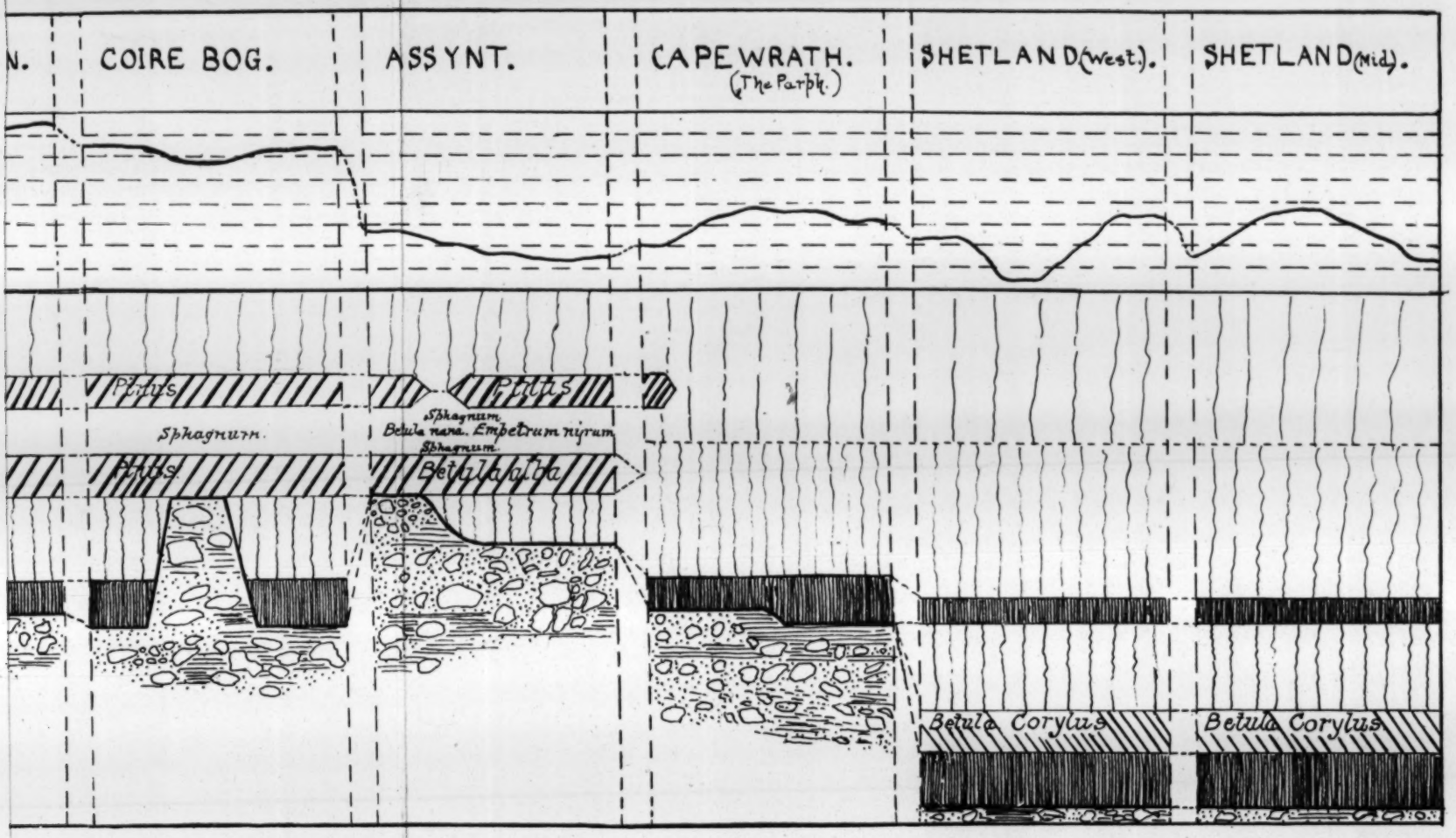
Betula al

Ajuga re

Salix pur

Elatine h

EQUENCE OF VEGETATION IN THE MOSSES ALONG THE LINE C.D. ON THE MAP.




MOSSES ALONG THE LINE A.B. ON THE MAP.

## PLANTS OCCURRING ONLY IN THE 1ST AND 2ND ARCTIC BEDS.

Salix reticulata. Salix herbacea. Salix Arbuscula.

Arctostaphylos alpina. Dryas octopetala. Betula nana.

Lychnis alpina. Veronica alpina.

Sedum Rhodiola. Empetrum nigrum. Sagina nodosa.

## PLANTS OCCURRING ONLY IN THE LOWER AND UPPER FOREST BEDS.

Betula alba. Corylus avellana. Alnus glutinosa.

Ajuga reptans. Ranunculus lingua. Pinus sylvestris.

Salix purpurea. Viburnum opulus (Cross Fell district)

Elatine hexandra (Cross Fell district)

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F. J. LEWIS: PLANT REMAINS IN SCOTTISH PEAT MOSSES.—PLATE III.

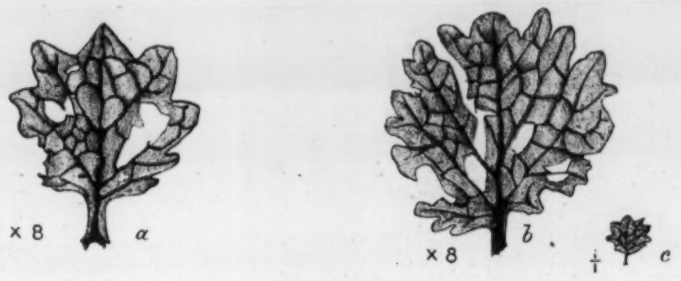


Fig. 1.

Fig. 2.

Fig. 3. Fig. 4. Fig. 5. Fig. 6. Fig. 7. Fig. 8.

Fig. 9. Fig. 10. Fig. 11.

Fig. 12.

Fig. 13. Fig. 14. Fig. 15.

McFarlane & Erskine, Lith. Edin.r

LEWIS: Plant Remains in the Scottish Peat Mosses. Part III.—PLATE IV.

FIG. 1.—The Upper Forest zone (*Pinus sylvestris*), Rannoch Muir.

FIG. 2.—Rannoch Muir. The vegetation consists of *Rhacomitrium lanuginosum*, *Scirpus cæspitosus*, and *Calluna*.

# III.—On the Source of the Amniotic and Allantoic Fluids in Mammals.

By D. Noël Paton, M.D., B. P. Watson, M.D., and James Kerr, B.Sc. (From the Research Laboratory of the Royal College of Physicians of Edinburgh, and the Physiological Department of the University of Glasgow.) *

(Read June 24, 1907. MS. received July 4, 1907. Issued separately December 16, 1907.)

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## I. Preliminary.

### 1. *Anatomical Considerations.*

In all vertebrates, as the embryo develops at one pole of the egg, it sinks inwards till it becomes completely enclosed in a hood or sac filled with fluid, the amnion. When the sac or true amnion has completely closed over the embryo, it becomes separated from the outer layer, which remains in contact with the covering of the egg as the false or chorionic amnion.

At first the amniotic sac is small and closed, but it rapidly becomes more and more distended with fluid as development advances, and when the hind gut opens upon the

* D. Noël Paton is responsible for the experiments recorded. The chemical examinations were carried out by him in conjunction with B. P. Watson, with the assistance of Mr A. Patterson. The analyses of the inorganic constituents were made by James Kerr, B.Sc., assisted by Mr James C. Kirkcaldie.

surface of the fœtus it communicates directly with the amniotic vesicle. When later the opening of the bowel differentiates from the urinary orifice, both anus and the meatus urinarius are in direct communication with the vesicle.

In reptiles, birds, and mammals another vesicle filled with fluid develops to a greater or less extent. This is the allantois. It is an outgrowth from the posterior end of the gut, which grows out in the mesoblast surrounding the amnion, and it may finally separate the amnion from the periphery of the ovum. From the first it is essentially a continuation of that part of the hind gut which will afterwards form the urinary bladder of the fœtus. In the wall of this vesicle, in most mammals, the blood-vessels of the embryo form a connection with the lining membrane of the uterus and produce a placenta.

In most of the lower mammals both vesicles are well developed; but in man and the anthropoid apes the allantois attains a very insignificant size and in man takes no part in the formation of the placenta.

The source of the fluids which fill these vesicles is still doubtful. In reptiles and birds they are necessarily fœtal in origin. The occurrence of urea and uric acid in the allantoic fluid of these animals, as was long ago demonstrated by JACOBSON and PREVOST (GUSSEROW, *Arch. f. Gynaekologie*, Bd. iii. p. 244, 1872), shows that in them the allantoic fluid is derived, in part at least, from the kidneys.

In mammals the question is not so simple, since the membranes surrounding one or both of the vesicles are in close relationship to the mucous membrane of the maternal uterus. The possibility is thus suggested that one or both fluids may be derived from the mother—a view which has been upheld by one set of authorities, and which is very commonly accepted in modern text-books of obstetrics. Other observers maintain that the fluids are fœtal in origin in the mammal as in the sauropsida.

A study of the anatomical relations of the membranes makes it difficult to accept the former hypothesis without very conclusive evidence in its favour. In most mammals the membrane of the allantois alone is in relation to the maternal mucous membrane; but it is always definitely separate from it, and is easily detachable.

The only connection between the fœtal and maternal circulation is through the placenta, which, although it varies greatly in distribution and complexity, is always essentially the same in structure—consisting of tufts of fœtal blood-vessels, carried out in the allantoic mesoblast, which have thrust their way into blood-spaces in the mucous membrane of the maternal uterus, so that the fœtal blood is brought into intimate relation with the maternal blood.

In all mammals fœtal blood-vessels run throughout the wall of the allantois—both in that part lying against the mucous membrane of the uterus, but separated from it by the chorionic amnion, and also in that part which surrounds the amniotic sac.

In man, while in the very early stage of development the ovum is attached all

round to the maternal mucosa by primitive chorionic villi, at the end of the third month of pregnancy the connection between chorion and mucosa breaks down as the placenta forms, and in all later stages is loose and non-vascular, except at the placental site. The connection between the outer layer of the amnion and the inner layer of the chorion is also loose, and can be readily separated even at full time.

Viewing the question from the anatomical standpoint, it is difficult to see how the fluids in these vesicles can be derived from the maternal blood.

### 2. *Pathological Evidence.*

This has been chiefly derived from the study of polyhydramnios and oligohydramnios in the human ovum. The most noteworthy of the recent observations on this subject is SILBERSTEIN'S (*Arch. f. Gyn.*, lxviii. 607, 1903). From a study of a 5½-months uni-ovular twin pregnancy, in which one of the sacs contained 6½ litres of fluid, while the other contained very little, he comes to the conclusion that part at least of the human liquor amnii is derived from the fœtal kidneys. In the sac containing the large quantity of fluid the fœtus was much larger than the other—783 grms. as contrasted with 488 grms. The heart of the polyhydramniotic fœtus was 7·5 grms., and that of the oligohydramniotic one, 3 grms.; the kidneys, 2·9 grms. each, as against 1 grm. each; and the bladder, 2·1 grms., as compared with 2 grms. The glomenuli in the kidneys of the larger fœtus had a diameter of 97 to 115 micros, while those of the smaller were only from 65 to 66 micros.

He concludes that, owing to the arrangement of the vascular areas of the two fœtuses in the common placenta, the larger fœtus had an extra supply of blood, part of which was directly diverted from the smaller one, and that as a result all the organs had hypertrophied, probably beginning with the heart. He considers the excess of liquor amnii in the sac as due to the consequent increased activity of the kidneys.

The mere fact of only one of the twin amniotic sacs having an excess of fluid is, of course, strong presumptive evidence of the fœtal origin of that fluid; but the evidence afforded that the fluid was secreted by the fœtal kidneys is not so convincing. Cases of hydramnios have been recorded in which there has been obstruction in the urethra and hydronephrosis in the fœtus (JAGGARD, *Am. Jour. Obst.*, xxix. p. 432, 1894). Like conditions in the fœtus have been found associated with oligohydramnios, as in cases recorded by BALLANTYNE (*Ed. Med. Jour.*, xl. 858, 1895) and BLACKWOOD (*Ed. Med. Jour.*, xli. 919, 1896); so that no definite conclusion, either in favour of or against the renal origin of the fluid, can be drawn.

In other cases the hydramnios has been found associated with conditions interfering with the circulation in the umbilical cord, such as excessive torsion, thrombosis of the vein, and cirrhosis of the liver (OPITZ, *Central. f. Gyn.*, 1898, p. 553). It is well known that hydramnios is often associated with malformations in the fœtus, such as

spina bifida, anencephaly, etc. But which is the primary condition has never been definitely ascertained. Altogether, very little light has been thrown upon the origin of the fluids from a study of pathological conditions in the human subject.

### 3. *Experimental Evidence.*

(1) *The Removal of the Fluids.*—It seemed to us that the effects of withdrawing the fluids might throw light upon the question of their origin, and one of us carried out a series of experiments on rabbits (WATSON, *Jour. of Obstet. and Gyn. of the British Empire*, Jan. 1906). The fluids were withdrawn from the uterus by an aspirator needle (the abdomen having been opened) at different periods of pregnancy. In the early stages of pregnancy, the fluid removed was yolk-sac fluid, and in the middle and later stages liquor amnii. In both cases the withdrawal resulted in immediate death of the fœtus, and this was followed by a degeneration of the fœtal part of the placenta. The maternal part of the placenta, on the other hand, continued to grow and to undergo the various histological changes which occur under normal circumstances. In no case, however, was there any re-formation of the liquor amnii. This would appear to indicate that in the rabbit the fluid must be fœtal in origin, since its secretion is arrested by the death of the fœtus, in spite of the fact that the fœtal part of the placenta does not show marked signs of degeneration for a few days, and the maternal part remains apparently normal up to the time it is cast off.

(2) *The Passage of Chemical Substances from the Mother to the Fluids.*—A large number of experiments have been recorded showing that chemical substances injected into the maternal circulation may appear in the fluids; and from certain of these the conclusion has been drawn that the fluids are formed directly from the maternal blood. The best known of these are by ZUNTZ (*Pflüg. Arch.*, Bd. xvi. p. 548, 1878).

The method he employed was that which had been already used by GUSSEROW in his classical investigations (*Arch. f. Gyn.*, Bd. iii. p. 241, 1872), and according to GUSSEROW by even earlier observers, *e.g.* MEYER (*Bischoffs Entwickelungsgeschichte*, p. 515). The substance used by ZUNTZ was sodium sulphindigotate, which he injected in large quantities into the veins of pregnant rabbits. He states that the amniotic fluid was coloured blue, while the kidneys and other tissues of the fœtus were free of the pigment, and that, when he killed the fœtus by injecting into it through the uterine wall caustic potash before injecting the pigment, in one experiment at least the pigment was detected in the fluid.

These observations were confirmed by WIENER for rabbits in the later stage of pregnancy (*Arch. f. Gyn.*, Bd. xvii. p. 24, 1881, and Bd. xxiii. p. 183, 1884). He further showed that the passage of pigment into the fœtal fluids was more rapid when the kidneys of the mother were first removed. In two pregnant dogs he entirely failed to find the pigment in the fœtal fluids, and he also failed in rabbits during the early stages of pregnancy.

It was thus in rabbits only that the passage of this colouring-matter to the fœtal fluids, without its presence having been detected in the fœtus, was observed by these investigators.

KRUKENBERG (*Arch. f. Gyn.*, Bd. xxii. p. 39, 1884) criticises their conclusions, pointing out that the recognition of sulphindigotate of soda in tissues is not easy, as was indicated by HEIDENHAIN (*Schultze's Arch.*, Bd. x. p. 35), who stated that, by injecting very small quantities, the urine may be made distinctly blue, while it is impossible to recognise the blue colour in the tissues. KRUKENBERG has repeated this experiment on the rabbit, and finds that, while the urine is distinctly blue, it is impossible to detect the pigment in the kidneys and liver. He does not prosecute the question of whether this is simply due to the small quantity of pigment, or whether "organic substances in close contact with small quantities of the pigment can decolorise it."

He further criticises the *experimentum crucis* of killing the fœtus by injecting caustic potash and then finding a slight blue coloration of the amniotic fluid. Certainly it seems possible that a traumatic communication might thus have been established between the maternal vessels and the fluids—a conclusion which is supported by the fact that in all experiments but one the red coloration of the fluid from extravasated blood prevented the detection of the blue pigment.

Opposed to the conclusion of ZUNTZ and WIENER are the experiments of GUSSEROW of injecting benzoic acid into the maternal blood and finding hippuric acid in the fœtal fluids. Accepting the conclusion of BUNGE and SMIEDEBERG that the synthesis of this substance takes place in the kidney, this observation favours the view that the fluids are produced from the embryonic kidney.

## II. PRESENT INVESTIGATIONS.

The unsatisfactory state of our knowledge as to the source of these fluids induced us to take up the question, and we have studied it by two different methods—first, by a continuation of the method of GUSSEROW, ZUNTZ, and others; and secondly, by a study of the chemistry of the fluids.

### 1. *The Part played by the Fœtus in the Passage of Substances from the Maternal Circulation to the Fluids.*

The objections to the use of the blue sodium sulphindigotate appeared to us so considerable that we have selected another pigment which is extremely easy to recognise in the smallest quantities, namely, fluorescin. We have also made experiments with three substances which are easily recognised by their colour reaction—sodium iodide, sodium ferrocyanide, and sodium salicylate.

For these experiments we have used the rabbit, guinea-pig, cat, and dog. The two

former are somewhat unsatisfactory, not only on account of their small size, but also from the fact that in both the development of the allantois is very incomplete. The same objection does not apply to the dog or cat, although in our hands the cat proved unsatisfactory, from the small amount of fluids in the later stages of gestation, when alone it was possible to be sure that the animals were pregnant.

The method of procedure was to anæsthetise the animal, to fix a cannula connected with a burette containing the solution to be injected in the proximal end of the jugular vein, and to let the solution run in very slowly. In some experiments one cornu of the uterus, with its contained pregnant sacs, was removed to serve as a check, but in later experiments this was not done.

When a sufficient quantity of the fluid had been run in—a good indication of this being given by the intense staining of the mucous membranes with the fluorescin—the injection was stopped and the animal allowed to live for from 10 to 20 minutes, being kept all the time under the anæsthetic. The uterus was then excised and the animal killed by pushing the anæsthetic.

The uterus was at once removed to a clean table, and each sac was carefully opened and the fluids collected in carefully cleaned vessels, care being taken to prevent any admixture with the maternal blood. The fœtuses were then removed, weighed, and if any urine was present in the bladder it was collected. Sometimes the fœtal blood was collected.

The presence of fluorescin was recognised by its fluorescent appearance even in the most dilute solution; and the amount was estimated by the intensity of the fluorescence.

Salicylic acid was tested for with a dilute solution of ferric perchloride, and the depth of colour gave a fair index of the amount present.

Sodium ferrocyanide was tested for with ferric chloride.

Sodium iodide was tested for by the method given in the Appendix.

The following experiment may be given *in extenso* as typical :—

Experiment IX.—Irish terrier bitch, about 13 kilos., supposed to be seven weeks pregnant.

On December 14, anæsthetised at 10.30, and two sacs of the right cornu of the uterus at once excised. A cannula placed in the jugular vein and the following solution run in from a burette :—

| | |
|---|---|
| Sodium iodide | 10 grms. |
| Sodium salicylate | 5 grms. |
| Fluorescin | 0·5 grms. |
| Water | 100 c.cm. |

The injection began at 11.12, and at 11.42, 150 c.c. had been injected (*i.e.* 15 grms. of sodium iodide, 7·5 grms. sodium salicylate, 0·75 grm. fluorescin). The dog was bled to death at 11.50. Eyes strongly fluorescent; skin and all the organs deeply stained. Blood-serum, bile, and urine intensely fluorescent.

| | Fœtus Weight. | Allantoic Amount. | Amniotic Amount. |
|---|---|---|---|
| The two sacs removed at the beginning of the experiment contained :— | | | |
| 1 | 109 | 24 | 12 |
| 2 | 105 | 28 | 15 |
| The six sacs removed after death contained :— | | | |
| 3 | 103 | 23 | 16 |
| 4 | 102 | 36 | 19 |
| 5 | 103 | 31 | 15 |
| 6 | 98 | 31 | 13 |
| 7 | 91 | 36 | 18 |
| 8 | Fœtus left in sac and fixed in formalin. | | |

None of the fluids were fluorescent except those of 7, which were distinctly so.

The allantoic and amniotic fluids of 4 and 7 gave a slight but distinct reaction of salicylic acid with ferric perchloride.

The combined urine collected from the bladders was strongly fluorescent, but the urine of 6 was free of fluorescence. The combined urine also gave a strong reaction of salicylic acid with ferric perchloride.

The fœtuses, the allantoic and amniotic fluids, and about 1 c.cm. of the combined urine were sent to Mr KERR, who reports as follows, as regards the presence of NaI :—

| Sample. | Presence of NaI. Total. | Per cent. |
|---|---|---|
| Fœtuses (1 and 2 check), 142 grms. | none | ... |
| „ (3 to 7), 223 grms. | 0·008 | 0·0036 |
| Fœtal urine, 2 c.c. | 0·00008 | 0·004 |
| Allantoic fluid, 140 c.c. | 0·0008 | 0·00057 |
| Amniotic fluid, 60 c.c. | 0·0004 | 0·0006 |

EXPERIMENT I.—Guinea-pig, 570 grms., nearly full time. Injected 0·29 grm. sodium ferrocyanide in $4\frac{1}{2}$ minutes. Killed after 15 minutes. Urine and kidney of mother gave marked reaction. Fœtal fluid and fœtal tissues gave no reaction. Maternal placenta gave a green colour.

EXPERIMENT II.—Cat, about 2000 grms., nearly full time. 0·8 grm. sodium ferrocyanide in 13 minutes. Animal killed after 20 minutes. Kidney and urine of mother gave very marked reaction. Fluids, tissues, and urine of fœtuses gave no reaction.

EXPERIMENT III.—Rabbit, about 24 days. Sodium sulphindigotate (not fully saturated), 38 c.c. injected in 11 minutes. The maternal urine was blue.

First sac removed 9 minutes after injection.
Fluids not coloured.
Urine „
Kidney „

Second sac, 19 minutes after injection.
Fluid faint green.
Urine not coloured.
Kidney ,,
Third sac, 34 minutes after injection.
Fluid not coloured.
Urine ,,
Kidney ,,

When mother killed, urine in bladder was green, but the kidneys were not coloured.

EXPERIMENT IV.—Rabbit, about 20 days. Fluorescin, 0·5 per cent., 10 c.c. in 6 minutes. Five minutes after, abdomen opened; abundant fluorescent ascitic exudation found. Ten minutes after, one cornu of uterus with three sacs excised. Membranes appeared fluorescent, but fluid was not so. The fœtal blood was not fluorescent. Fifteen minutes after, the other cornu was removed, and gave the same characters. The urine and tissue of the mother were strongly fluorescent.

EXPERIMENT V.—Guinea-pig, about 650 grms. 20 c.c. of 0·5 per cent. fluorescin in 8 minutes. Animal killed after 15 minutes. All the maternal tissues markedly fluorescent. No colour in fluids or in tissues of fœtuses.

EXPERIMENT VI.—Rabbit, almost full time. 20 c.c. 10 per cent. sodium iodide in 12 minutes. Animal killed 13 minutes after. Two sacs, one with exomphalotic and anencephalic fœtus, other with normal fœtus but no fluids.

EXPERIMENT VII.—Rabbit, 12–14 days. One sac excised as control. 20 c.c. sodium iodide (10 per cent.) in 13 minutes. Killed 12 minutes after. Amniotic fluid of six sacs mixed—also allantoic. Report :—

| Sample. | Presence of Iodide. |
|---|---|
| Maternal urine | strongly marked. |
| Amniotic fluid | none. |
| Allantoic fluid | distinct trace. |
| Control fœtus | none. |
| Fœtuses (6) after injection | strongly marked. |

EXPERIMENT VIII.—Rabbit, 17 days. Control sac excised. 20 c.c. sodium iodide (10 per cent.) in 9 minutes. Animal died 6 minutes after injection stopped. The fluids of the remaining six sacs were mixed. Report :—

| Sample. | Presence of Iodide. |
|---|---|
| Maternal urine | very strongly marked. |
| Mixed fluids after injection | distinct trace. |
| Fœtus | strongly marked. |
| Control fluids | none. |
| Control fœtus | none. |

EXPERIMENT IX.—Already described in detail.

EXPERIMENT X.—Guinea-pig, nearly full time. One fœtus of 92 grms. 20 c.c. of 1 per cent. fluorescin in 10 per cent. sodium iodide in 5 minutes. Animal killed 10

minutes after. Maternal blood fluorescent, but urine not so. Fluids not distinctly fluorescent. Fœtal blood distinctly fluorescent. Report:—

| Sample. | Presence of Iodide.* |
|---|---|
| Maternal blood | 0·026 grm. |
| Fœtus | none. |
| Fluids | none. |
| Fœtal blood | 0·002 grm. |
| Maternal urine | 0·0003 grm. |

EXPERIMENT XI.—Guinea-pig, nearly full time. Two fœtuses about 80 grms. 17·5 c.c. of same solution in 5 minutes. Animal killed after 10 minutes. Maternal blood fluorescent. Fœtal blood fluorescent. Fluids slightly fluorescent. Report:—

| Sample. | Presence of Iodide.* |
|---|---|
| Maternal blood | 0·012 grm. |
| Fœtuses | 0·002 grm. |
| Fœtal blood | present. |
| Fluids | 0·00006 grm. |

EXPERIMENT XII.—Cat. 45 c.c. solution of sodium iodide 10 per cent., sodium salicylate 5 per cent., sodium sulphindigotate to saturation, were injected in 23 minutes. The animal died. Mucous membranes, all connective tissues, and muscles intensely blue. Medulla of kidney blue, cortex green. Liver and spleen not blue; but when cut and exposed to air the surface of liver became greenish blue. Intestines deep blue, but when left covered by other coils lost their blue colour. Urine intensely blue, with red shimmer. Wall of uterus deep blue. Blood-plasma deep blue.

Four sacs. Fœtuses almost full time, weighing about 75 grms. each.

Fœtal organs and blood gave no trace of blue.

Fœtal urine, about 1 c.c., gave no trace of blue, but one drop gave a faint brown with $FeCl_3$, indicating the presence of salicylic acid.

Allantoic fluid of brown colour. No blue tinge. Gave faint deepening of brown with $FeCl_3$.

Amniotic fluid.—No trace of blue. Slight brown with $FeCl_3$. Report states that there is a considerable quantity of iodide in the maternal urine (17 c.c.) and in the maternal blood (56 c.c.), but only a trace in the allantoic fluid (7 c.c.) and in the amniotic fluids (13 c.c.), and a trace in the four fœtuses (300 grms.) = 0·0012 grm.

Twelve experiments have thus been performed—five on rabbits, four on guinea-pigs, two on cats, and one on a dog.

Sodium ferrocyanide has been injected twice, sodium sulphindigotate twice, sodium iodide seven times, fluorescin five times, and sodium salicylate twice.

The following table gives the general result of these experiments, arranged under

* In these two experiments the percentage of iodide present cannot be given, as the weights of the specimens were not noted.

the different substances injected. The intensity of the reaction is indicated by the signs 0, −, +, + +, and + + + indicating the most intense reaction.

| Substance Used and Species of Animal. | Fœtus. | | | Mother. | | |
|---|---|---|---|---|---|---|
| | Fluids. | Tissues. | Urine. | Urine. | Kidney. | Blood. |
| **Sodium Iodide.** | | | | | | |
| Guinea-pig | 0 | 0 | − | ... | ... | + |
| „ | − | + | ... | ... | ... | + |
| Rabbit | Am. 0 All. − | + + | ... | + + | ... | ... |
| „ | − | + + | ... | + + + | ... | ... |
| „ | Am. + All. 0 | + + | ... | ... | ... | ... |
| „ | „ + „ ... | + + | ... | ... | ... | ... |
| Dog | „ − „ − | + | + | + | ... | ... |
| **Sodium Ferrocyanide.** | | | | | | |
| Guinea-pig | 0 | 0 | ... | + | + | .... |
| Cat | 0 | 0 | ... | + | + | ... |
| **Fluorescin.** | | | | | | |
| Guinea-pig | 0 | 0 | ... | + | + | + |
| Rabbit | 0 | 0 | ... | + | + | + |
| „ | ... | ... | ... | ... | ... | ... |
| „ | ... | ... | ... | ... | ... | ... |
| Dog | Am. − ? All. − ? | + | + | + + | ... | + + |
| **Sodium Salicylate.** | | | | | | |
| Rabbit | ... | ... | ... | + | ... | ... |
| Rabbit | ... | ... | ... | + | ... | ... |
| Dog | Am. − All. − | + | + | + + | ... | ... |
| **Sodium Sulphindigotate.** | | | | | | |
| Rabbit | ? | 0 | ... | + | 0 | ... |
| Cat | Am. 0 All. 0 | 0 | 0 | + | + | + |

These experiments show (1) that, with the one very doubtful exception of sodium sulphindigotate in one sac in the rabbit in Experiment III., in no case did the substance injected into the maternal circulation appear in the fluids without also being present in the fœtus; and (2) that, when the substance appeared in the fluids, its amount in the fœtal tissues or fœtal urine was always much greater. The unsatisfactory nature of sodium sulphindigotate for such investigations is well shown by Experiment XII.

*They therefore show that the transference of material from the mother to the fluids takes place through the fœtus.*

D. J. Copper (*Der Übergang bestimmtes Stoffe von der Mutter in das Fruchtwasser und in den Fötus.* Utrecht, 1905) gives the results of three quantitative determinations

of iodides in the fluids and in the fœtal urine after their injection into two pregnant cows and one pregnant goat. In the two cows he finds the iodide in greater percentage amount in the amniotic fluid than in the urine; while in the goat he finds it in about the same amount in the amniotic, but to a less amount in the allantoic than in the blood of the fœtus.

The very consistent results which we obtained with a series of chemical substances, in our opinion, counterbalances the value of these two observations, especially as the method employed by us in the determination of the amount of iodine present is more satisfactory than that used by COPPER.

But COPPER does not attempt to argue in favour of the direct passage of the iodide from the maternal blood, but he believes that it passes through the maternal placenta to the chorionic villi of the fœtal placenta, and that from the efferent vessels of this it is carried into the wall of the allantoic vesicle, which surrounds the amnion, and that from there it passes into the fluids.

GUSSEROW (*Arch. f. Gyn.*, Bd. iii. p. 241, 1872) had already indicated the possible importance of the vessels running over the placenta.

COPPER has repeated upon ruminants the experiments previously performed by TOERNGREN (*C.R. Soc. biol.*, 1888, p. 543) on rabbits, of injecting iodides into the amniotic sac and recovering them in the maternal urine. Such observations seem to prove no more than that iodides are taken up by the blood-vessels in the walls of the allantois and so carried to the placenta to be passed into the maternal circulation. They do not in any way indicate that these fluids are formed from the maternal blood-vessels.*

### 2. *The Mode of Production of the Fluids by the Fœtus.*

It having been shown that the fluids and their constituents are fœtal in origin, the question of how they are produced has next to be considered.

(1) They may be produced as a transudation from the blood-vessels coursing in the walls of the vesicles, which, as has been indicated, are purely fœtal in nature.

(2) They may be derived from the kidneys of the fœtus.

(3) They may be derived from both these sources.

(4) One fluid may be formed from the other to a greater or less extent, or each may derive constituents from the other by diffusion or osmosis through the amniotic and allantoic membranes which separate them.

The question of the parts played by (1) transudation from the blood-vessels of the allantois and (2) by the action of the fœtal kidneys may first be considered.

It must be at once admitted that the small amount of fluid which is included in the amniotic sac at the time of its development must have an origin independent of blood-vessels and kidneys, and must be derived from a breaking-down or secretory

* COPPER gives a very excellent summary of the previous work on the subject.

action of the cells of the ovum. With this earliest production of the fluid we are not concerned.

In the sheep, the earliest pregnancies examined by us contained embryos of about 1·5 grm. in weight, and in these the kidneys and the allantoic blood-vessels are both well developed and the urethra differentiated, while there is something less than 10 c.c. of amniotic and about 50 c.c. of allantoic fluid.

Before the end of pregnancy these fluids had increased, the amniotic to an average of about 560 c.c., and the allantoic to 90 or 100 c.c.

In the rabbit, the allantoic circulation and the development of the kidney are completed at about the ninth day.

From an early stage of pregnancy both the factors under consideration are therefore capable of playing a part in the formation of these fluids, and the evidence as to the part played by each may now be examined.

(1) *The Evidence afforded by the Study of the Molecular Concentration of the Amniotic and Allantoic Fluids and of the Maternal and Fœtal Blood.*—A good many observations have been carried out along these lines by means of the cryoscope, in the hope of determining whether the fluids are secretions or transudates. The most satisfactory are those by JACQUÉ and those by GRÜNBAUM.

JACQUÉ (*Bull. de l'Acad. de Belgique*, 1902, p. 218) has examined the allantoic and amniotic fluids of the sheep cryoscopically in order to determine their molecular concentration. This he found always inferior to that of the blood, either fœtal or maternal—allantoic fluid, Δ 0·522; amniotic fluid, Δ 0·538; maternal blood, Δ 0·578; fœtal blood, Δ 0·623. From this he concludes that the origin of the fluids is not by transudation but by renal secretion. Further, by observations carried out at different periods of gestation, he finds that the molecular concentration of the two fluids varies. Thus, during the first stages of development, when the allantoic sac communicates freely with the bladder of the fœtus, the concentration of the allantoic fluid is lower than that of the fœtal urine, and lower than that of the amniotic fluid. At a later period, when the urachus is still patent and the urethra communicates with the amniotic cavity, the liquor amnii and the liquor allantoidis are of the same concentration; while in the later stages of development, when the urachus is closed but the urethra still communicates with the amniotic cavity, the amniotic fluid has a higher molecular concentration than the allantoic. From this he concludes that in the early stages the allantoic fluid is derived from the fœtal kidneys through the urachus, and that the amniotic fluid is derived from it by the abstraction of water. In the later stages the amniotic fluid is derived directly from the fœtal kidneys by the urethra, and the allantoic is derived from the amniotic by a passage of water back through the membranes.

Less satisfactory cryoscopic investigations have been carried out by KEIM (*Bullet. de la Société d'Obstétrique*, 1901), and by BILLARD, DIEULAFÉ, and GILLES (*Comp. Rend. de la Soc. de Biolog.*, 1905), and they conclude that in the early stages of

development there is a current from the maternal blood-serum to the amnion, and in the later stages a current in the reverse direction from amnion to maternal blood-serum.

GRÜNBAUM (*Verhand. de physic. med. Gesellsch. zu Würzburg*, Bd. xxvii., No. 3, p. 161, 1905; abstract *Maly's Jahresbericht* for 1905) found that the amniotic fluid had a lower molecular concentration than the maternal blood. The freezing-point reduction of the blood is 0·53, of the fœtal fluids 0·485, and of the fœtal urine 0·2.

In the cow, the molecular concentration of the amniotic fluid is nearly that of the blood till the end of pregnancy, when it becomes less. In the allantoic, the molecular concentration is at first very little different from that of the blood, later distinctly less, and towards the end of pregnancy again becoming nearly the same as the blood. So far as they were investigated, the dog, cat, and goat gave the same results as the cow. In the pig, the amniotic fluid shows a lower concentration than the blood in the second half of pregnancy, and the allantoic a lesser concentration. From these observations he concludes that in man the amniotic fluid is a mixture of transudation and fœtal urine, and that in the cow the amniotic fluid is entirely a transudation, the allantoic fluid in the beginning a transudation and later chiefly fœtal urine.

The author appears to conclude that, when molecular concentration of one of the fœtal fluids approaches that of the blood, the fluid is to be regarded as a transudation, while if the molecular concentration is lower an admixture with urine is indicated.

Considering the enormous variations in the relationship between the molecular concentration of the urine and blood in the adult, such a conclusion appears hardly warranted. While normally the $\Delta$ of the blood is 0·56° C., and that of the urine 2·3, the $\Delta$ of the urine may in the caffeine diuresis or after drinking large quantities of beer fall as low as ·160.

Again, the study of the absorption of fluids from serous spaces has shown that the molecular concentration of an effusion may be raised by the absorption from it of water. Thus, alterations in the molecular concentration of the fœtal fluids may be capable of explanation in terms of the relative activity of formation on the one hand and absorption on the other.

The conclusions arrived at by the study of the molecular concentration of the fluids have thus a somewhat unsatisfactory basis.

It appeared to us that more light might be thrown upon the question of the relative part played by transudation on the one hand, and secretion by the kidneys on the other, by a more careful analysis of the results of our experiments on the injection of substances into the maternal blood, and a study of the chemistry of the fluids.

(2) *Evidence from the injection of Substances into the Maternal Blood.*—The most convincing experiment is No. IX., on a bitch. Here fluorescin, sodium salicylate, and sodium iodide were injected. The combined urines of the fœtuses were very strongly fluorescent, but the fluids of only one pregnancy sac showed a slight fluorescence. The fœtal urines gave strongly the reaction for salicylic acid, but the

combined fluids gave only a faint although a distinct reaction. For the sodium iodide the figures show :—

| | |
|---|---|
| Fœtal urine . . . . . | ·04 per mille. |
| Allantoic fluid . . . . . | ·0057 „ |
| Amniotic fluid . . . . . | ·0066 „ |

There was nearly ten times as much in the fœtal urine as in the fluids. Such observations seem to indicate that secretion from the kidneys alone would explain the appearance of these substances in the fluids.

(3) *Chemical Examination of Fluids.*—The marked differences in the chemical constitution of urine and of exudations from blood-vessels justified us in hoping that a study of the chemistry of the fluids would throw important light upon their nature. Although a good many isolated observations on the chemistry of these fluids have been recorded, few systematic studies of the subject have been made. The best of these is by Döderlein (*Arch. f. Gyn.*, xxxvii., Heft i. p. 141, 1890), who carried out an extended series of observations on the amount, physical characters, and chemical constitution of the fluids in the cow throughout pregnancy. Curiously enough, he failed to observe some important points, and, in our opinion, failed also to appreciate the significance of his own evidnce.

Kestiakowski, in *La Physiologiste Russe*, 1898–99, p. 155, gives a series of analyses of the amniotic fluid of the cow at different stages of pregnancy, and he concludes that in the early part of pregnancy it is derived from the vessels of the placenta, and that in the later months it is an excretion from the organs of digestion. His analyses did not include the investigation of the non-protein nitrogen, and he thus failed to understand the significance of the presence of the urinary constituents in the fluids.

For our investigations we have chiefly used the sheep, because (1) it is easy to get a considerable number of pregnant uteruses from the slaughter-house; (2) in the sheep the allantoic and amniotic sacs are both well developed.

More recently these observations have been extended by the examination of the fluids of the cow, pig, and dog.

The results may be considered under the following heads:—

(*a*) Amount, character, and specific gravity of each fluid at different stages of pregnancy.

(*b*) The occurrence or non-occurrence of proteins in the fluids of various animals.

(*c*) The amount, character, and distribution of the non-protein nitrogen.

(*d*) The pigments.

(*e*) The occurrence of sugar; its nature and amount, and its relationship to the non-protein nitrogen.

(*f*) The ash of the fluids.

(*a*) *Amount and Specific Gravity of the Fluids.*—The following tables give the results of our observations during 1905–6 on the sheep. Table A gives the individual observation. Table B gives the average result at different stages of pregnancy.

TABLE A.

QUANTITY OF AMNIOTIC AND ALLANTOIC FLUIDS, AND THEIR SPECIFIC GRAVITY.

| Amniotic Fluid. | | | Allantoic Fluid. | |
|---|---|---|---|---|
| Weight of Fœtus, grms. | Quantity, c.c. | Sp. Gr. | Quantity, c.c. | Sp. Gr. |
| 1·5 | 2 | ... | 10 | ... |
| 1·8 | 30 | 1008·6 | 125 | 1006·4 |
| 3·4 | 30 | ... | 55 | 1009·4 |
| 5 | 15 | ... | ... | ... |
| 8 | 150 | ... | 80 | 1012 |
| 8 | 28 | 1008 | 20 | 1010 |
| 10 | 86 | 1013 | 132 | 1012 |
| 10 | 40 | ... | 28 | ... |
| 12 | 100 | 1013 | 117 | 1013 |
| 13 | 58 | ... | 45 | ... |
| 13 | 60 | ... | 30 | ... |
| 14 | 150 | 1011 | 59 | 1014 |
| 16 | 70 | 1012 | 16 | ... |
| 18 | 130 | 1011 | 120 | 1012 |
| 18 | 135 | 1012 | 85 | 1015 |
| 18 | 140 | 1011 | 30 | 1014 |
| 22 | 50 | 1012 | 60 | ... |
| 25 | 150 | 1012 | 32 | ... |
| 25 | 170 | 1010 | 16 | ... |
| 28 | 305 | 1011 | 240 | 1013 |
| 32 | 70 | 1010 | 90 | 1012 |
| 35 | 180 | 1012 | 130 | 1014 |
| 35 | 210 | ... | 45 | ... |
| 40 | 350 | 1011 | 60 | 1014 |
| 42 | 170 | 1011·5 | 236 | 1012·5 |
| 47 | 170 | ... | 14+ | ... |
| 50 | 240 | 1011 | 60 | 1014 |
| 53 | 134 | ... | 56 | ... |
| 55 | 260 | 1011 | 60 | 1014 |
| 80 | 300 | ... | ... | ... |
| 85 | 245 | ... | 35 | ... |
| 153 | 235 | ... | ... | ... |
| 195 | 250 | 1012 | 42 | ... |
| 196 | 700 | 1012 | ... | ... |
| 245 | 480 | ... | 70 | ... |
| 250 | 480 | 1011 | 35 | 1015 |
| 253 | 504 | 1011 | ... | ... |
| 270 | 950 | 1012 | 20 | ... |
| 295 | 400 | ... | ... | ... |
| 328 | 420 | 1010 | ... | ... |
| 337 | 340 | ... | 52 | ... |
| 340 | 450 | ... | ... | ... |
| 390 | 320 | 1012 | 104 | 1020 |
| 390 | 525 | ... | 54 | ... |
| 430 | 475 | ... | 18 | ... |
| 50 | 500 | 1012 | 60 | 1016 |
| 455 | 380 | ... | 50 | ... |
| 478 | 500 | ... | 70 | ... |

TABLE A.—*continued.*

| Amniotic Fluid. | | | Allantoic Fluid. | |
|---|---|---|---|---|
| Weight of Fœtus, grms. | Quantity, c.c. | Sp. Gr. | Quantity, c.c. | Sp. Gr. |
| 500 | 270 | 1011 | 90 | 1021 |
| 530 | 315 | 1010 | ... | ... |
| 565 | 650 | 1011 | 134 | 1022 |
| 570 | 220 | 1012 | 192 | 1017 |
| 620 | 350 | ... | 60 | ... |
| 655 | 370 | ... | ... | ... |
| 720 | 600 | 1016 | ... | ... |
| 815 | 680 | ... | 70 | ... |
| 865 | 300 | ... | 106 | ... |
| 1505 | 750 | 1014 | 60 | 1024 |
| 1670 | 575 | ... | 54 | ... |
| 1670 | 520 | ... | 110 | 1022 |
| 2010 | 410 | 1012 | 145 | 1020 |

TABLE B.

AVERAGE AMOUNTS OF AMNIOTIC AND ALLANTOIC FLUIDS, AND THEIR SPECIFIC GRAVITY, AT DIFFERENT STAGES OF PREGNANCY.

| Amniotic. | | | | Allantoic. | | |
|---|---|---|---|---|---|---|
| Weight of Fœtus, grms. | No. of Observations. | Quantity, c.c. | Sp. Gr. | No. of Observations. | Quantity, c.c. | Sp. Gr. |
| Below 15 | 12 | 57 | 1011 | 11 | 66 | 1011 |
| 15 to 30 | 8 | 144 | 1011 | 8 | 73 | 1013·5 |
| 30 to 100 | 11 | 205 | 1011 | 9 | 96 | 1013·4 |
| 100 to 300 | 8 | 499 | 1012 | 4 | 41 | 1015 |
| 300 to 1000 | 18 | 425 | 1012 | 13 | 86 | 1019 |
| Over 1000 | 4 | 564 | 1013 | 4 | 92 | 1022 |

DÖDERLEIN (*loc. cit.*, p. 149) found in the cow a marked and rapid increase in the amniotic fluid in the first half of pregnancy, and then a very marked fall towards the end; and an almost continuous increase in the allantoic fluid—an increase which became more marked in the second half of pregnancy, when the amniotic fluid was decreasing.

We have been unable to procure the original papers of MAJEWSKI (*De substantiarum quæ liquoribus amnii et allantoidis insinit*: Dissertatio, Dorpat, 1858) on herbivora, or those of TSCHERNOW (*De liquorum embryonalicum in animalibus carnivoris*: Dissertatio, Dorpat, 1858), referred to by DÖDERLEIN, p. 145.

Our own few observations on the cow support DÖDERLEIN's results, as is shown in the appended table (C):—

TABLE C.

| Weight of Fœtus, grms. | No. | Allantoic. | | Amniotic. | |
|---|---|---|---|---|---|
| | | Present Observations. | DÖDERLEIN. | Present Observations. | DÖDERLEIN. |
| About 100 . . . | 2 | 332 | 90 | 247 | 160 |
| 600 to 700 . . . | 3 | 700 | 850 | 2730 | 2000 |
| 3000 to 4000 . . . | 3 | 1800 | 2000 | 2500 | 3200 |
| About 9000 . . . | 1 | 3900 | 6500 | 460 | 1200 |

In the pig we have made seven observations, which give the following average amounts of fluid in each gestation sac with different lengths of embryo:—

| Length of Embryo in cms. | Amniotic Fluid in c.cms. | Allantoic Fluid in c.cms. |
|---|---|---|
| 2·5 | 1·1 | 135 |
| 3·0 | 1·4 | 130 |
| 3·0 | 1·5 | 144 |
| 8·0 | 17·0 | 135 |
| 10·0 | 41·0 | 170 |
| 17·0 | 75·0 | 155 |
| 24·0 | 70·0 | 180 |

This shows the same increase in the amniotic fluids as occurs in the sheep, with the same comparatively small increase in the amount of allantoic fluid.

*Amount.*—In the animals examined, the *amniotic fluid* is at first small in amount, but rapidly increases, and in the sheep and cow reaches its maximum about the middle of pregnancy, after which it undergoes no very marked change in the sheep, but very markedly decreases in the cow. The allantoic fluid in the earlier part of pregnancy is larger in amount than the amniotic, but in the later stages it may show hardly any increase, as in the sheep, or it may increase enormously, as in the cow.

Possibly these different relations depend upon the extent to which the amniotic fluid is swallowed by the fœtus and re-excreted through the patent urachus into the allantoic vesicle. It is further possible that, in the middle period of pregnancy, before the muscular structures round the urethra are formed, the urine secreted passes equally into both sacs, but that in the later months in some animals, *e.g.* the cow, it may generally pass into the allantoic sac, and only occasionally by micturition into the amniotic.

*Specific Gravity.*—The allantoic fluid shows a marked increase in specific gravity. The amniotic fluid shows hardly any increase in its specific gravity.

(*b*) *Proteins of the Fluids.*—Transudations from blood-vessels contain the proteins of the blood-plasma. In determining the source of the fluids, it was therefore necessary to examine them for the presence or absence of such proteins.

The qualitative examination was made by acidifying and boiling for the detection of albumins and globulins, and by the addition of ESBACH'S solution for the detection of lower proteins.

The following table gives the results :—

TABLE D.

| | Allantoic. | Amniotic. |
|---|---|---|
| Sheep (61) . . . . . | + | 0 |
| Cow (9) . . . . . | + | + |
| Pig (7) . . . . . | + | + |
| Cat (2) . . . . . | + | + |
| Dog (1) . . . . . | 0 | + |

KESTIAKOWSKI records the presence of albumin in the amniotic fluid of the cow during the early stages of pregnancy only, and the presence of mucin in the later stages.

The variations in the amount of proteins in the allantoic fluid throughout pregnancy were studied in the sheep by precipitating either by boiling with addition of acetic acid, or by the addition of an equal quantity of a 10 per cent solution of trichloracetic acid, and weighing.

The following table gives the results :—

TABLE E.

| Weight of Fœtus in grms. | Per cent. of Protein in Allantoic Fluid. | Average Percentage. |
|---|---|---|
| 2 | 0·125 | |
| 10 | 0·40 | |
| 10 | 0·51 | |
| 12 | 0·45 | |
| 13 | 0·30 | |
| 13 | 0·54 | |
| | —— | 0·42 |
| 40 | 0·89 | |
| 47 | 0·33 | |
| | —— | 0·61 |
| 200 | 0·65 | |
| 390 | 0·48 | |
| 150 to 650 | 0·38 | |
| 400 | 0·61 | |
| 400 to 800 | 0·86 | |
| 600 | 0·26 | |
| | —— | 0·53 |
| 1500 | 0·48 | |
| 1670 | 0·46 | |
| | —— | 0·47 |

They show that the amount of protein varies little throughout the greater part of pregnancy.

According to DÖDERLEIN's observations on the cow, the amount of proteins in both fluids rises throughout pregnancy in the amniotic from ·042 to ·45, and in the allantoic from 0·3 to 1·37.

In the dog, six weeks pregnant with embryos of 35 grms., the allantoic fluid was free of proteins, but the amniotic contained distinct amounts of native proteins amounting to ·06 per cent.

In another dog, said to be seven weeks pregnant, and with fœtuses averaging 100 grms. in weight, a mere trace of protein was found in the allantoic fluid, while a very distinct amount was present in the amniotic.

In the pig's uterus at various stages of pregnancy both amniotic and allantoic fluids contained native proteins, the former 0·495 per cent., the latter 0·563 per cent.

The proportion of albumin and globulin was determined in four cases in the sheep :—

TABLE F.

PROPORTION OF ALBUMIN AND GLOBULIN IN ALLANTOIC FLUID.

| Numbers of Fluids mixed. | Weight of Fœtuses, grms. | Total Protein. | Per cent. of Albumin. | Globulin | $\frac{A}{G}$ |
|---|---|---|---|---|---|
| 3 | 40 to 50 | ·335 | ·268 | ·067 | 4 |
| 5 | 300 to 500 | ·610 | ·460 | ·150 | 3 |
| ? | 500 to 600 | ·380 | ·283 | ·097 | 3 |
| 1 | 600 | ·265 | ·235 | ·040 | 5 |

The fact that coagulable proteins do not exist in the amniotic fluid of the sheep seems to oppose the view that it is formed as a transudation from blood-vessels, because, so far as we at present know, all such transudations contain the proteins of the blood-plasma.

On the other hand, their presence in the allantoic fluid of the sheep, and in both fluids in the other animals observed, does not oppose the view that these fluids are formed in the kidneys.

The opportunity of examining fœtal urine is not often afforded, because the bladder is generally empty. DÖDERLEIN (*op. cit.*, p. 155) gives two analyses, one of the urine of a fœtus of 15,000 grms. and another of a newly-born calf. In the first there was 0·33 per cent., in the second 0·18 per cent., of proteins. In the urine of two fœtal sheep, one of 1505 grms. and one of 1630 grms.—nearly full time—we found coagulable proteins present. This is confirmatory of the old observations of DZARDI in 1806, that alcohol causes a white gelatinous precipitate in the urine of the new-born calf, and of those of VIRCHOW, MARTIN RUGE and BIEDERMANN, and of DOHRN in the new-born child (quoted by DÖDERLEIN, *loc. cit.*, p. 172). JACQUÉ (*loc. cit.*) also records the presence of albumin in the urine of fœtal sheep.

(*c*) *Non-Protein Nitrogen and its Distribution.*—While the absence of native proteins affords evidence of some value against the origin of the fluids by transudation, and while their presence does not militate against the idea that the fluids are of renal origin, a study of the presence of non-protein nitrogen, and the nature of the compounds in which it occurs, should throw light on the relation of the fluids to fœtal urine.

The total nitrogen was determined in 5 or 10 c.c. by KJELDAHL'S method. In the allantoic fluids the total proteins were determined by precipitation with trichloracetic acid, and the nitrogen either estimated directly or calculated from the weight of the precipitate. This was subtracted from the total nitrogen, and the non-protein nitrogen was thus obtained.

The urea nitrogen was determined generally by the method of MÖRNER and SJÖQUIST, sometimes also by the method of BOHLAND. By the former method a considerable quantity of any allantoin present is estimated with the urea, and by the latter method all is probably so estimated. The results of the earlier analyses were rejected, as the amount of fluid taken (5 c.c.) proved to be too small to yield an adequate amount of ammonia for accurate titration.

Generally the urea results by BOHLAND'S method were considerably higher than those by MÖRNER'S, especially in the case of the allantoic fluids.

TABLE G.

DISTRIBUTION OF NITROGEN IN AMNIOTIC AND ALLANTOIC FLUIDS.

| Amniotic. | | | | Allantoic. | | | | |
|---|---|---|---|---|---|---|---|---|
| Weight of Fœtus. | Total N. | M. and S. N. | Per cent. | Total N. | Protein N. | Non-Protein N. | M. and S. N. | Per cent. of M. and S. to Non-Protein N. |
| 1·8 | ·0368 | ·024 | 64 | ·0688 | ... | ... | ·0324 | ... |
| 5 | ·0536 | ... | ... | ·137 | ·093 | ·044 | ... | ... |
| 8 | ·048 | ·0312 | 65 | ·106 | ... | ... | ·0312 | ... |
| 8 | ... | ... | ... | ·126 | ... | ... | ·0524 | ... |
| 10 | ·0256 | ·02 | 78 | ... | ... | ... | ... | ... |
| 10 | ·0592 | ·0424 | 72 | ·157 | ·0816 | ·076 | ·0536 | 70 |
| 13 | ... | ... | ... | ·154 | ·048 | ·106 | ·0704 | 66 |
| 13 | ... | ... | ... | ·171 | ·086 | ·085 | ·0648 | 76 |
| 30 | ·0256 | ·02 | 78 | ·316 | ·198 | ·116 | ·0592 | 50 |
| 32 | ·0592 | ·0508 | 86 | ·157 | ... | ... | ... | ... |
| 35 | ·0592 | ... | ... | ·226 | ·143 | ·123 | ·0536 | 43 |
| 41 | ·0212 | ·0156 | 73 | ·161 | ·054 | ·107 | ·0744 | 69 |
| 150 | ·066 | ·055 | 83 | ... | ... | ... | ... | ... |
| 195 | ·048 | ... | ... | ·328 | ·101 | ·227 | ... | ... |
| 196 | ·134 | ... | ... | ... | ... | ... | ... | ... |
| 250 | ·14 | ·101 | 72 | ·302 | ·041 | ·261 | ·137 | 52 |
| 253 | ·0648 | ·062 | ... | ... | ... | ... | ... | ... |
| 270 | ·132 | ... | ... | ... | ... | ... | ... | ... |
| 328 | ·0368 | ·0312 | 84 | ... | ... | ... | ... | ... |
| 370 | ·06 | ·0398 | 66 | ·332 | ·0976 | ·235 | ·15 | 63 |
| 390 | ·076 | ... | ... | ·276 | ·0777 | ·198 | ... | ... |

TABLE G—*continued.*

| Amniotic. | | | | Allantoic. | | | | |
|---|---|---|---|---|---|---|---|---|
| Weight of Fœtus. | Total N. | M. and S. N. | Per cent. | Total N. | Protein N. | Non-Protein N. | M. and S. N. | Per cent. of M. and S. to Non-Protein N. |
| 450 | ... | ... | ... | ·339 | ·06 | ·279 | ... | ... |
| 512 | ·0928 | ... | ... | ·434 | ·137 | ·297 | ·16 | 53 |
| 560 | ·0872 | ·076 | 87 | ·277 | ·0608 | ·216 | ·0704 | 32 |
| 720 | ·0424 | ·02 | 62 | ... | ... | ... | ... | ... |
| 740 | ·0443 | ·0356 | 80 | ·225 | ·064 | ·161 | ·066 | 38 |
| 1505 | ... | ... | ... | ·371 | ·0837 | ·287 | ... | 60 |
| 1670 | ·1404 | ·104 | 74 | ·227 | ·073 | ·154 | ·0928 | ... |
| 1670 | ·102 | ·066 | 64 | ... | ... | ... | ... | ... |

TABLE H.

PERCENTAGE OF NON-PROTEIN NITROGEN IN AMNIOTIC AND ALLANTOIC FLUIDS AT DIFFERENT STAGES OF PREGNANCY.

| Weight of Fœtus, grms. | Amniotic. | | Allantoic. | |
|---|---|---|---|---|
| | No. of Observations. | Per cent. of Nitrogen. | No. of Observations. | Per cent. of Nitrogen. |
| Below 15 . . . . | 5 | ·044 | 4 | ·077 |
| 30 to 100 . . . . | 3 | ·046 | 2 | ·115 |
| 100 to 300 . . . | 6 | ·097 | 2 | ·244 |
| 300 to 1000 . . . | 7 | ·062 | 6 | ·23 |
| Over 1000 . . . . | 2 | ·121 | 2 | ·22 |

TABLE I.

PERCENTAGE OF M. AND S. NITROGEN IN AMNIOTIC AND ALLANTOIC FLUIDS AT DIFFERENT STAGES OF PREGNANCY, AND ITS RELATION TO THE TOTAL NON-PROTEIN NITROGEN.

| Weight of Fœtus, grms. | Amniotic. | | | Allantoic. | | |
|---|---|---|---|---|---|---|
| | No. of Observations. | M. and S. N. | Per cent. of M. and S. N. to Total Non-Protein N. | No. of Observations. | M. and S. N. | Per cent. of M. and S. N. to Total Non-Protein N. |
| Below 15 . . | 4 | ·029 | 69 | 6 | ·0508 | 70 |
| 30 to 100 . . | 2 | ·033 | 79 | 2 | ·063 | 55 |
| 100 to 300 . . | 3 | ·072 | 77 | 1 | ·137 | 52 |
| 300 to 1000 . . | 5 | ·0405 | 75 | 4 | ·094 | 46 |
| Over 1000 . . | 2 | ·085 | 69 | 1 | ·092 | 60 |

The results of our determination of the non-protein nitrogen show that excretory products are constantly present in both fluids throughout the whole of pregnancy, and that in the sheep, as DÖDERLEIN found in the cow, an increase occurs as pregnancy advances. From the beginning and throughout the whole time the amount is higher in the allantoic than in the amniotic fluid.

The study of the distribution of nitrogen in the various excretory substances is still under investigation, but the observations so far made show—

1st. That in the amniotic fluid somewhere between 70 and 80 per cent. of the nitrogen is in the form of urea (or allantoin?), and that the proportion is not altered throughout the course of pregnancy.

2nd. That in the allantoic fluid only about 50 to 70 per cent. of the nitrogen is in urea and allantoin.

That a large amount of this nitrogen of the amniotic fluid is urea has been demonstrated by the separation of urea as the oxalate.

*The constant occurrence of nitrogen in simple combinations, and the fact that a considerable proportion of this is urea, is a strong argument in favour of the view that both allantoic and amniotic fluids are derived from the fœtal kidney.*

(*d*) *Pigment.*—At the beginning of pregnancy both allantoic and amniotic fluids are colourless, the amniotic fluid being water-clear and the allantoic slightly turbid; but in the later stages the amniotic fluid of the sheep becomes of an amber-yellow colour. In the cow the allantoic fluid has the same colour, but the amniotic fluid often becomes colourless.

After shaking with ether a brown fluid is left, which *gives the spectrum of urobilin. This further indicates the renal origin of the fluid.*

(*e*) *Sugar.*—The earliest record of the presence of sugar in the fœtal fluids which we have found is by MAJEWSKI (*loc. cit.*, 1858). Subsequent observers, *e.g.* DÖDERLEIN, have failed to observe it.

We have found it to be a constant constituent of both allantoic and amniotic fluids of the sheep, cow, pig, cat, and dog, and of the mixed fluids of the rabbit, ferret, and guinea-pig.

The *variations in its amount* in the two fluids throughout pregnancy have been studied in the sheep. The analyses were made in the usual manner by FEHLING's method. The results are given in the following tables (K and L):—

TABLE K.

DISTRIBUTION OF SUGAR IN AMNIOTIC AND ALLANTOIC FLUIDS.

| Weight of Fœtus, grms. | Amniotic Fluid. Per cent. of sugar. | Allantoic Fluid. Per cent. of sugar. |
|---|---|---|
| 5 | ·15 | ·417 |
| 8 | ·078 | ·5 |
| 10 | ·058 | ·29 |
| 12 | ·073 | ·5 |
| 13 | ·058 | ·34 |
| 35 | ·08 | ·37 |
| 41 | ·078 | ·413 |
| 42 | ·077 | ·27 |
| 80 | ·083 | ... |
| 270 | ·263 | ... |
| 295 | ·113 | ·415 |
| 328 | ·240 | ... |
| 370 | ·123 | ·268 |
| 390 | ·166 | ·71 |
| 450 | ·21 | ... |
| 480 | ·17 | ... |
| 512 | ·25 | ·44 |
| 530 | ·31 | ... |
| 550 | ·217 | ... |
| 560 | ·265 | ·634 |
| 720 | ·51 | ... |
| 740 | ·161 | ·247 |
| 1505 | ·347 | ... |
| 1670 | ·78 | ·33 |

TABLE L.

PERCENTAGE OF SUGAR IN AMNIOTIC AND ALLANTOIC FLUIDS AT DIFFERENT STAGES OF PREGNANCY.

| Weight of Fœtus, grms. | No. of Observations. | Amniotic Fluid. Per cent. | No. of Observations. | Allantoic Fluid. Per cent. |
|---|---|---|---|---|
| Below 15 | 5 | ·083 | 5 | ·409 |
| 30 to 100 | 4 | ·079 | 3 | ·351 |
| 100 to 300 | 2 | ·188 | 1 | ·415 |
| 300 to 1000 | 11 | ·235 | 5 | ·477 |
| Over 1000 | 2 | ·563 | 1 | ·33 |

In the allantoic fluid the amount varies little, being ·409 per cent. in the earlier pregnancies, ·438 per cent. in the later stages.

In the amniotic fluid the percentage is at first small—only ·083—and it rises in the later period to ·287—an increase of more than threefold; but it is always smaller than the percentage in the allantoic, except possibly at the very end of gestation.

In a cow about the middle of pregnancy the percentage was :—

| | |
|---|---|
| Allantoic . . . . . | 1·00 per cent. |
| Amniotic . . . . . | 0·277 „ |

*Nature of the Sugar.*—The sugar in the amniotic and allantoic fluids of the sheep and cow reduces FEHLING's solution, ferments with yeast, and yields crystals with the character of glucosazone. But it is lævo-rotatory and gives SELIWANOFF's lævulose reaction. It is therefore the ketose, lævulose. In the allantoic fluid of the dog, the sugar was in such small amounts that its nature could not be investigated.

GÜRBER and GRÜNBAUM (*Munch. med. Wochen.*, 1904, 377) have already recorded the presence of lævulose in these fluids in the sheep, cow, and goat.

*Source of the Sugar.*—The following facts indicate that the sugar is derived from the fœtus:—

1st. We have found the same sugar in the fœtal urine of the sheep to the extent of 0·5 to 0·7 per cent.

2nd. It is present in the fœtal blood. By extracting large quantities of fœtal blood with alcohol, evaporating with charcoal, and taking up in a small quantity of water, we were able to extract a sugar which was lævo-rotatory and which gave SELIWANOFF's reaction distinctly. The fact that it occurs in larger amounts in the urine than in the blood indicates that its presence is not simply due to the swallowing of amniotic fluid by the fœtus. In one case the amount of sugar in the blood was as much as 0·42 per cent.

We have been unable to demonstrate this sugar in the liver. The amount of carbohydrate present in that organ in the fœtal lamb seems to be very small. CHIPMAN

TABLE M.

NITROGEN-SUGAR RELATIONS.

| Weight of Fœtus, grms. | Amniotic. | | | Allantoic. | | |
|---|---|---|---|---|---|---|
| | Non-Protein Nitrogen. | Sugar (G). | $\frac{G}{N}$ | Non-Protein Nitrogen. | Sugar (G). | $\frac{G}{N}$ |
| 5 | ·0536 | ·15 | 2·7 | ·044 | ·417 | 9 |
| 8 | ·0256 | ·078 | 3 | ... | ... | ... |
| 10 | ·0592 | ·058 | 0·9 | ·075 | ·29 | 3·8 |
| 13 | ·037 | ·058 | 1·5 | ·085 | ·34 | 4 |
| 35 | ·0592 | ·08 | 1·3 | ·123 | ·37 | 3 |
| 46 | ·0212 | ·078 | 3·6 | ·107 | ·413 | 3·8 |
| 270 | ·132 | ·263 | 2 | ... | ... | ... |
| 295 | ·02 | ·113 | 5·6 | ... | ... | ... |
| 328 | ·036 | ·24 | 6·6 | ... | ... | ... |
| 350 | ·06 | ·123 | 2·5 | ·235 | ·268 | 1·1 |
| 390 | ·076 | ·166 | 2·1 | ·198 | ·71 | 3·5 |
| 512 | ·0928 | ·25 | 2·6 | ·297 | ·44 | 1·4 |
| 530 | ·0536 | ·31 | 5·7 | ... | ... | ... |
| 550 | ·02 | ·217 | 10·8 | ... | ... | ... |
| 560 | ·0872 | ·265 | 3 | ·2168 | ·634 | 2·8 |
| 720 | ·0424 | ·51 | 12 | ... | ... | ... |
| 740 | ·0331 | ·161 | 4·8 | ·173 | ·247 | 1·4 |
| 1670 | ·1404 | ·78 | 5 | ·154 | ·33 | 2·1 |

(*Reports from the Laboratory of the Royal College of Physicians of Edinburgh*, vol. viii., 1903) found glycogen absent from the fœtal rabbit on the 22nd day, but present in the placenta from the 8th day.

*The demonstration of the origin of the lævulose from the fœtus and of its presence in such considerable quantities in the fœtal urine is further proof that the fœtal fluids are derived from the fœtal kidneys.*

The presence of lævulose as a normal constituent of the blood and urine of the fœtus is of considerable interest in connection with the occurrence of cases of lævulosuria in man without any apparent cause.

The relationship of the sugar to the non-protein nitrogen throughout pregnancy is of interest. While in the amniotic fluid the sugar is increased threefold and the nitrogen undergoes a much smaller increase, in the allantoic fluid the nitrogen is increased more than threefold, while the sugar undergoes only a slight rise.

The proportion between nitrogen and sugar thus varies as is shown in Tables M and N.

TABLE N.

RELATIONSHIP OF SUGAR TO NON-PROTEIN NITROGEN AT DIFFERENT STAGES OF PREGNANCY.

| Weight of Fœtus, grms. | $\frac{G}{N}$ | |
|---|---|---|
| | Amniotic. | Allantoic. |
| Below 15 . . . | 2 | 5·6 |
| 30 to 100 . . . | 2·4 | 3·4 |
| 100 to 300 . . | 3·8 | ... |
| 300 to 1670 . . | 5·7 | 2·05 |

(*f*) *Salts.*—The salts of the fœtal fluids in the cow throughout pregnancy have been investigated by DÖDERLEIN (*loc. cit.*, p. 161 *et seq.*). He finds the chlorides are higher in amount in the amniotic than in the allantoic fluid, and that in both fluids the percentage varies little throughout pregnancy. The average, as NaCl, is in the amniotic fluid 0·59 per cent., and in the allantoic 0·23. The sodium behaves like the chlorine. Potassium remains constant at about 0·05 per cent. in the amniotic fluid, but in the allantoic fluid it increases from 0·03 to 0·13. He finds a very marked difference in the percentage of magnesium in the two fluids, it being almost absent from the amniotic, but present in the allantoic to the extent of 0·01 to 0·05 per cent.

Our analyses give the following results. The methods used are given in the Appendix.

TABLE O.

INORGANIC CONSTITUENTS OF AMNIOTIC AND ALLANTOIC FLUIDS.

| | Sheep. | | | | | Cow. | | | | Pig. |
|---|---|---|---|---|---|---|---|---|---|---|
| Size of Embryos . . . | 1670 grms. | 155 to 650 grms. | About 25 grms. | 2010 grms. | 480 grms. | About 2000 grms. | About 3000 grms. | About 3000 grms. | 3200 grms. | |
| **Amniotic Fluid.** | | | | | | | | | | |
| Volume sent, in c.cm. . . | 400 | 1000 | 150 | 410 | 333 | 75 | 375 | 378 | 250 | 217 |
| Grms. per 100 c.c. of fluid— | | | | | | | | | | |
| Cl . | 0·349 | 0·425 | 0·432 | 0·344 | ... | 0·444 | 0·429 | 0·429 | 0·425 | 0·257 |
| $PO_4$ . | 0·044 | 0·019 | ... | 0·014 | ... | ... | ... | ... | 0·002 | ... |
| $SO_4$ . | 0·094 | 0·037 | ... | 0·043 | 0·018 | 0·012 | 0·010 | 0·009 | 0·032 | 0·023 |
| Ca . | 0·005 | 0·007 | 0·006 | 0·007 | 0·007 | 0·005 | 0·006 | 0·005 | 0·005 | 0·011 |
| Mg . | ... | 0·003 | 0·001 | 0·003 | 0·002 | 0·001 | 0·002 | 0·001 | 0·003 | 0·002 |
| K . | ... | 0·006 | 0·083 | 0·040 | ... | ... | ... | ... | 0·033 | ... |
| Na . | ... | 0·295 | 0·291 | 0·281 | ... | ... | ... | ... | 0·300 | ... |
| **Allantoic Fluid.** | | | | | | | | | | |
| Volume sent . . . | ... | 130 | 75 | 145 | 129 | 345 | 318 | 368 | 200 | 450 |
| Cl . | ... | 0·143 | 0·342 | 0·088 | ... | 0·317 | 0·138 | 0·082 | 0·082 | 0·153 |
| $PO_4$ . | ... | 0·045 | ... | 0·044 | ... | ... | ... | ... | 0·017 | ... |
| $SO_4$ . | ... | 0·482 | ... | 0·340 | 0·285 | 0·028 | 0·146 | 0·117 | 0·204 | 0·029 |
| Ca . | ... | 0·010 | 0·012 | 0·003 | 0·035 | 0·016 | 0·004 | 0·013 | 0·003 | 0·017 |
| Mg . | ... | 0·018 | 0·006 | 0·015 | 0·022 | 0·004 | 0·013 | 0·016 | 0·032 | 0·002 |
| K . | ... | 0·070 | 0·063 | 0·152 | ... | ... | ... | ... | 0·006 | ... |
| Na . | ... | 0·216 | 0·222 | 0·188 | ... | ... | ... | ... | 0·168 | ... |

Our results on the cow and sheep confirm the observations of DÖDERLEIN, as is shown in the accompanying table, in the top line of which the averages of all the figures given by DÖDERLEIN are shown, and in the second line the averages of our results are given—

| | | Ca. | Mg. | Na. | K. | Cl. | $PO_4$. | $SO_4$. |
|---|---|---|---|---|---|---|---|---|
| Amniotic | DÖDERLEIN'S Results . | *·009 | *·003 | ·271 | ·048 | ·359 | ... | ... |
| | Present Results . . | ·006 | ·002 | ·291 | ·055 | ·393 | ·02 | ·031 |
| Allantoic | DÖDERLEIN'S Results . | *·013 | *·032 | ·125 | ·083 | ·140 | ... | ... |
| | Present Results . . | ·013 | ·014 | ·198 | ·073 | ·168 | ·035 | ·204 |

We further find—what DÖDERLEIN did not record—an excess of phosphorus and sulphur compounds in the allantoic fluid. Our single examination of the fluid in the pig does not show the differences in the magnesium and calcium contents of the fluids which are observed in ruminants.

DÖDERLEIN lays great stress upon the distribution of these inorganic constituents, maintaining that the high content of the amniotic fluid in chlorine and sodium indicates its origin as a transudate from the plasma, and that the large amount of magnesium in the allantoic fluid indicates its origin from the kidneys. But VIERORDT

* These results should be lower, as in some cases he gives "traces."

(*Daten und Tabellen*, p. 333) gives a table based upon analyses of SCHMIDT and VOGEL showing a content of NaCl in the blood-plasma of 0·5546 per cent., and in the urine of 1·10 per cent., while in flesh and many other constituents of the body the proportion of magnesium is greater than that of calcium. It seems unsatisfactory to attempt to draw conclusions as to the source of the fluids from their inorganic constituents.

## III. SUMMARY OF EVIDENCE AND CONCLUSIONS.

To sum up the evidence at our disposal :—

1. As against the fluids being of maternal origin, it has been shown :—

1st. That anatomically this is improbable.

2nd. That pathological evidence gives no support to the idea.

3rd. That, after the fœtus has been killed by withdrawing the fluid, no re-formation of the amniotic fluid occurs, although the maternal uterus and placenta remain normal.

4th. That various substances injected into the maternal vessels appear in the fluids only after first being in the fœtus.

The only evidence in favour of the maternal origin of the fluids is the experimental work of ZUNTZ and WIENER with sulphindigotate of soda on rabbits—the probable fallacies of which have been explained.

2. As against either of the fluids being formed as a transudation from the fœtal blood-vessels in the wall of the allantois may be adduced :—

1st. The absence of the proteins of the blood-plasma from the amniotic fluid of the sheep and from the allantoic fluid of the dog. Their presence in the fluids of other animals cannot be considered as indicating their origin as transudations, since these proteins are present in fœtal urine.

2nd. The observations recorded on the molecular concentration of the fluids and on the changes which this undergoes throughout pregnancy afford no evidence of their formation as transudations.

The only evidence of an exchange between these vessels and the fluids is the fact that sodium iodide is so readily absorbed from the fluids and passed through the placenta into the maternal circulation. But the absorption of such a substance into the blood-vessels does not prove that normally fluid passes from these vessels into the fœtal fluids, any more than its absorption from the bladder proves that normally the urine is secreted from the bladder wall.

3. That the fluids are of the nature of urine derived by secretion from the fœtal kidney is indicated by the following facts :—

1st. The anatomical connection of the two cavities with the fœtal urinary system.

2nd. Both fluids contain a considerable proportion of nitrogen in urea and allied compounds.

3rd. The existence of a peculiar sugar—lævulose—in the fluids, and also in the fœtal urine.

4th. Proteins, which are generally, although not always, present in the fluids, have been found in the fœtal urine.

5th. GUSSEROW observed that, when benzoic acid is injected into the mother, hippuric acid appears in the fœtal fluids.

6th. Such substances as sodium iodide, sodium salicylate, and fluorescin, which, when injected into the maternal circulation, appear in the fœtal fluids, are found in much greater abundance in the fœtal urine and tissues.

All investigators who have recognised the fœtal origin of the fluids admit that the allantoic fluid is at least mainly urinary in nature, but it has been maintained by most that the amniotic fluid is a transudation.

Thus ELLENBERGER (*Vergleichende Physiologie der Haussäugthiere*, Bd. ii. p. 523, 1892) says: "The amniotic fluid is a transudation from the rich cutaneous vessels of the embryo; later it is also possibly derived from the vessels of the allantois which surround the amnion, . . . into which, towards the end of pregnancy, urine and saliva may escape."

DÖDERLEIN also regards the amniotic fluid as a transudation, basing his conclusion entirely upon the correspondence between the salts of the fluid and those of the blood-plasma, and ignoring his own results upon the non-protein nitrogen and the other evidence which is forthcoming.

The last question which must be discussed is a very difficult one. Admitting the origin of both fluids as essentially a secretion from the fœtal kidneys, does any exchange go on between the fluids, separated as they are by only a thin double membrane?

The facts to be taken into consideration in dealing with this question seem to be the following. They are diagrammatically represented in fig. 2:—

1st. The relatively rapid increase of the amniotic fluid as compared with the allantoic.

2nd. The steady increase of the sp. gr. of the allantoic fluid without any change in the sp. gr. of the amniotic, and the fact that in the early stages the sp. gr. of the two fluids is the same.

3rd. The steady increase of non-protein nitrogen in the allantoic fluid, and the slighter increase of the nitrogen of the amniotic fluid.

4th. The high proportion of urea nitrogen in the amniotic fluid and the steady decrease in the proportion of urea nitrogen in the allantoic fluid.

5th. The steady increase of sugar in the amniotic fluid, so that at the end of pregnancy it becomes equal to, or greater than, the percentage in the allantoic, which from the beginning remains fairly steady.

6th. The high chlorine content of the amniotic fluid as compared with the allantoic throughout pregnancy, and the low magnesium content of the same fluid.

The higher chlorine and possibly the higher sodium content (DÖDERLEIN, KERR), with

the higher molecular concentration found both by JACQUÉ and GRÜNBAUM (fig. 1), of the amniotic fluid early in pregnancy might cause an osmosis of water from the allantoic to the amniotic sac (fig. 3). This might account for a concentration of the allantoic fluid and the rise in the sp. gr. and in the non-protein nitrogen; and, if the amniotic fluid

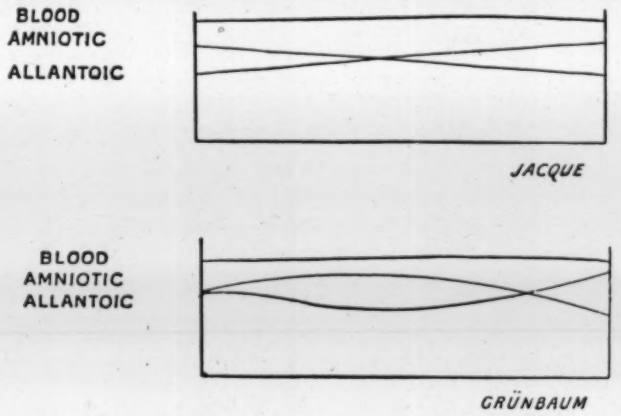


FIG. 1.—To show changes in the molecular concentration of the fluids throughout gestation.

were also being added to from the kidneys, it might explain the slight change in the sp. gr. and in the non-protein nitrogen in the amniotic fluid.

On the other hand, diffusion might explain the passage of sugar and of the nitrogen in the form of readily diffusible urea from the allantoic to the amniotic fluid, thus

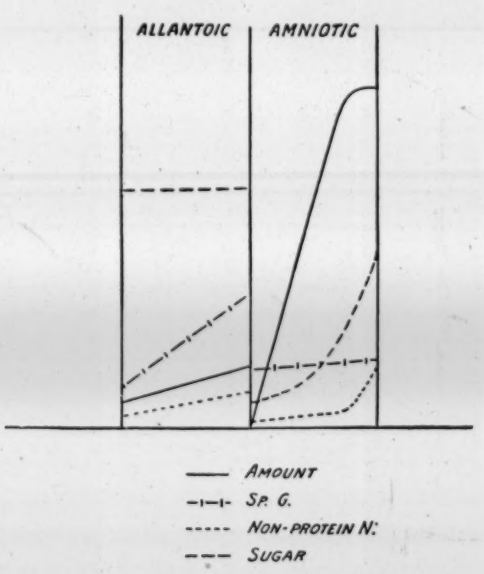


FIG. 2.

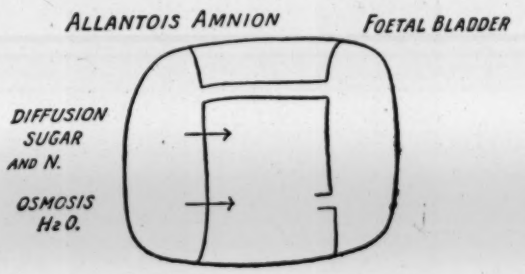


FIG. 3.

raising the percentage of sugar in the amnion and maintaining the percentage of non-protein nitrogen (fig. 3).

The absence of further increase in the amniotic fluid in the later stages of pregnancy may be due partly to the fœtus swallowing the fluid, and, in the cow at least, passing it into the allantoic sac; but it may in part be due to the rise in the molecular concentration of the allantoic fluid (JACQUÉ and GRÜNBAUM) arresting the osmotic stream. This would

not interfere with the diffusion of sugar, and hence the percentage of that substance in the amnion would tend to rise till it equalled that in the allantoic fluid. But if such exchanges go on, it is difficult to explain the persistence of the high chlorine content of the amniotic fluid. Why should it not pass into the allantoic fluid? Or is it possible that the passage of water and diffusible solids can take place only from allantois to amnion, but not in the reverse direction?

The whole question of these exchanges is further complicated by :—

(*a*) The continuous addition of urine to the allantoic fluid.

(*b*) The intermittent addition of urine to the amniotic fluid.

(*c*) The possible absorption of allantoic or even of amniotic fluid by the blood-vessels going to the placenta.

These various considerations do not affect our main thesis, that *both fœtal fluids are essentially derived from the fœtus through the kidney.*

Our thanks are due to Mr A. M. Trotter, M.R.C.V.S., for his kindness in procuring for us a considerable amount of the material used in these investigations.

## APPENDIX.

### The Method used for Detection and Estimation of Iodide.

The process employed for the detection and approximate determination of the iodide was as follows :—

The specimen was ignited to ash after addition of solid sodium carbonate. The ash was boiled with water, filtered, concentrated to definite volume.

A measured volume of the solution was taken, such that it contained not more than 0·0005 gramme of iodide calculated as sodium iodide, 1 c.c. of chloroform added, and 1 c.c. of concentrated solution of potassium nitrite, and the mixture acidified with dilute sulphuric acid.

The colour of the resulting solution of iodine in chloroform was then compared with the colour obtained by the same process from a standard solution of iodide.

The smallest quantity of iodide which could be detected by this method was equivalent to 0·000036 gramme of sodium iodide.

A blank experiment was conducted, and gave no indication of iodide.

### Determination of Chloride.

A measured quantity of fluid was evaporated to dryness in a platinum basin, after addition of some pure solid sodium carbonate.

The residue was carefully carbonised, digested with dilute nitric acid, and to the solution a measured excess of standard silver nitrate solution was added.

The precipitated silver chloride was filtered off, and the excess of silver nitrate in

the filtrate was determined by means of standard ammonium thiocyanate solution, using ferric sulphate solution as indicator.

The difference between the amount of silver nitrate added and the amount found after precipitation of chloride was calculated into the equivalent amount of chlorine.

### Determination of Total Sulphur.

The total sulphur was determined by igniting with sodium carbonate and potassium nitrate, dissolving the ash in dilute hydrochloric acid, and precipitating with barium chloride solution.

The weight of barium sulphate obtained, multiplied by the factor 0·41146, gave the proportion of total sulphur expressed as $SO_4$.

### Determination of Total Phosphorus.

The total phosphorus was determined by igniting with sodium carbonate and potassium nitrate, dissolving the ash in dilute nitric acid, and precipitating the boiling-hot solution with a boiling-hot solution of ammonium molybdate in presence of ammonium nitrate and nitric acid.

The precipitated ammonium phospho-molybdate was filtered, washed with a mixture of ammonium nitrate and nitric acid solutions, dissolved in ammonia, the solution heated to the boiling-point, and the ammonium phospho-molybdate re-precipitated by addition of boiling-hot nitric acid solution.

The precipitated ammonium phospho-molybdate was filtered through a Gooch's crucible, washed with ammonium nitrate and nitric acid solution, and heated at 160° C. until the weight was constant.

The weight of ammonium phospho-molybdate found, multiplied by the factor 0·05022, gave the proportion of total phosphorus expressed as $PO_4$.

### Determination of Calcium and Magnesium.

The ash from a portion of the fluid was dissolved in dilute hydrochloric acid, filtered, warmed, made alkaline with ammonia, and then acidified with acetic acid.

The calcium was precipitated by addition of ammonium oxalate, the mixture heated for some time, and then filtered. The precipitate was ignited in a platinum basin, then moistened with dilute sulphuric acid, dried, ignited, and weighed as calcium sulphate.

The weight of calcium sulphate, multiplied by 0·29450, gave the proportion of calcium compounds expressed as Ca.

In the filtrate from the calcium oxalate, the magnesium was precipitated by sodium phosphate and ammonia as magnesium ammonium phosphate.

After standing twenty-four hours this was filtered off, washed with dilute ammonia

solution, ignited in a porcelain crucible over a blowpipe, and weighed as magnesium pyrophosphate.

This, multiplied by the factor 0·21875, gave the proportion of magnesium compounds expressed as Mg.

### Determination of Potassium and Sodium.

A measured volume of the fluid was evaporated to dryness in a platinum basin and carefully ignited over a low flame. The ash was dissolved in dilute hydrochloric acid and filtered. The filter was ignited, dissolved in dilute hydrochloric acid, and the solution filtered.

The *mixed filtrates* were made alkaline with barium hydroxide solution, warmed for some time and filtered. The filtrate was evaporated to small volume, and the excess of barium removed by repeated treatment with ammonium carbonate and filtration. Finally, the filtrate was acidified with hydrochloric acid, made alkaline with ammonia, and evaporated to dryness. The ammonium salts were then burnt off in a platinum basin at a low temperature, and the residue weighed. This residue was dissolved in water and filtered. The filter was washed, burnt, and weighed, and its weight subtracted from that of the undissolved residue.

The resultant is the weight of the mixed alkali chlorides.

The filtrate was treated with excess of hydrochloro-platinic acid, evaporated to dryness on water-bath, treated with 85 per cent. alcohol, and filtered. The precipitate was washed with 85 per cent. alcohol, and dissolved through the paper with boiling distilled water. The solution was collected in a small weighed beaker, in which it was carefully evaporated to dryness, dried at 130° C. and weighed.

The weight of potassium chloro-platinate thus obtained, multiplied by the factor 0·3056, gave the weight of potassium chloride.

By deducting the weight of potassium chloride from the total weight of alkali chlorides obtained above, the proportion of sodium chloride present was determined.

The weight of potassium chloride found, multiplied by the factor 0·52479, gave the proportion of potassium compounds expressed as K.

The weight of sodium chloride found, multiplied by the factor 0·39401, gave the proportion of sodium compounds expressed as Na.

# IV.—Report on Fossil Fishes collected by the Geological Survey of Scotland from Shales exposed on the Shore near Gullane, East Lothian. By Ramsay H. Traquair, M.D., LL.D., F.R.S. (With Two Plates.)

(Read May 6, 1907. MS. received May 25, 1907. Issued separately December 21, 1907.)

In the year 1903 Mr Macconochie made an interesting collection of fossil fish-remains from beds of Lower Carboniferous age exposed on the seashore near Gullane, in East Lothian, which were submitted to me for determination by the Director of the Geological Survey. Accordingly, I prepared a preliminary account of these remains, which was published in the *Summary of Progress* for the year above mentioned.

Since that time Mr Macconochie has collected additional specimens from the same locality, which has also been visited by several private collectors, to whom I am indebted for kindly permitting me to examine and record the specimens which they obtained. So, with the sanction of the Director, I propose to devote this paper to a detailed, as well as illustrated, account of the results obtained by the searching of the beds in this new Scottish locality for Carboniferous Fossil Fishes.

The locality in question is situated on the shore about two miles north-east of Gullane, and three and a half miles straight west from the centre of the town of North Berwick. I am informed that locally the spot is known as "Cheese Bay," on account of a ship laden with cheese having been wrecked there. Here three beds lying pretty close together have yielded fossil fishes, and these, commencing with the lowest, may be noted as under.

*Bed a.* A soft shale of about 2 feet in thickness, showing on cross fracture a fine banded coloration; layers of a dark purplish grey about $\frac{1}{8}$ inch in thickness alternating with others of lesser depth and paler appearance; but the proportions of these bands are not always the same, and frequently they are considerably thinner than the size given above. This is the bed which has yielded the greatest number of species of fishes, although to obtain any at all much patient labour is necessary.

*Bed b.* Above this fish-bed lie several feet of shale, partly partaking of the nature of an oil-shale, and on the top of this is a band, the presence of fish-remains in which was first detected by Mr John Muir. The shale constituting this band is very fissile, weathering with ochreous stains, and containing many coprolites; but the fishes which it contains are few in point of species and badly preserved.

*Bed c.* Resting on this last-mentioned fish-bearing shale is a hard, ferruginous cement-stone band, about six inches in thickness, containing numerous specimens of small crustacea such as *Tealliocaris Loudonensis*, Peach. A few fishes occur in this band, which is, however, much more productive in the Arthropoda referred to, and which are mostly in a very fine state of preservation.

We may now proceed to the enumeration and, where necessary, the description of the fishes and fish-remains which have occurred in these beds.

## Class PISCES.

### Subclass ELASMOBRANCHII.

### Order ACANTHODEI.

### Family ACANTHODIDÆ.

### Genus *Acanthodes*, Agassiz.

### *Acanthodes*, sp. indet.

The collection submitted to me contains four fragmentary specimens referable to this genus, but of which it is not possible to define the species with accuracy. The best of these is a portion, $2\frac{1}{2}$ inches in length, of the hinder extremity of a fish, showing the dorsal and anal spines, but cut off just at the origin of the caudal fin. The minute quadrate scales have mostly a small dimple in the centre of the outer surface.

Though I hesitate to affix a specific name to these fragments, I rather suspect they will turn out to belong to the same species as the fragment from Wardie named by AGASSIZ *A. sulcatus* (*Poiss. Foss.*, vol. ii., pt. 1, 1835, p. 125, pl. 1 *c*, figs. 1, 2).

### Subclass TELEOSTOMI.

### Order CROSSOPTERYGII.

### Family RHIZODONTIDÆ.

### Genus *Rhizodus*, Owen.

### *Rhizodus Hibberti* (Agassiz and Hibbert).

1836. *Megalichthys Hibberti*, Agassiz and Hibbert, *Trans. Roy. Soc. Edinb.*, vol. xiii. p. 202, pl. viii. fig. 1 (*non* figs. 2 and 3), pl. ix. figs. 2, 3, 9, 10; woodcut on p. 183.
1841. *Rhizodus Hibberti*, Owen, *Odontography*, vol. i. p. 75, vol. ii. p. 12, pl. xxxv. fig. 2, pls. xxxvi., xxxvii.
1844. *Holoptychius Hibberti*, Agassiz, *Poiss. Foss.*, vol. ii. pt. ii. p. 180 (name only).
1855. *Rhizodus Hibberti*, M'Coy, *Brit. Palæoz. Foss.*, p. 612.
,, *Rhizodus gracilis*, M'Coy, *ibid.*, p. 611, pl. iii. G, fig. 17.
1877. *Rhizodus Hibberti*, R. H. Traquair, *Proc. Roy. Soc. Edinb.*, vol. ix. p. 658.
1891. ,, ,, A. S. Woodward, *Cat. Foss. Fishes Brit. Mus.*, pt. ii. p. 342.
1899. *Megalichthys Hibberti*, O. P. Hay, *American Naturalist*, vol. xxxiii., 1899, p. 787.

Two scales, one of which measures 3 inches in diameter, have been found by Mr MACCONOCHIE in bed *a*, and one large tooth $2\frac{1}{2}$ inches in length, deficient at the point, by Mr W. T. GORDON in bed *b*.

There can be no doubt that this is the fish to which AGASSIZ originally applied the term *Megalichthys*, in allusion to the great bulk which it must have attained, as testified to by the gigantic teeth and scales, which were the first of its relics to come into the hands of Dr HIBBERT; and there can also be no doubt that, according to the strict laws of nomenclature, *Megalichthys* is still its legitimate generic name. It is true that AGASSIZ confounded its remains with those of a rhombic-scaled Osteolepid, which he afterwards (1844) described and figured under the name of *Megalichthys Hibberti*, while erroneously relegating the original *Megalichthys* to the genus *Holoptychius*. But priority for the application of the name *Megalichthys* to the fish now under consideration was secured eight years previously by the fact that HIBBERT, in pl. viii. of his well-known Burdiehouse memoir, quoted above, figured under that name one of its large teeth as fig. 1, while the rhombic scale of the Osteolepid appeared on the same plate as fig. 3. I am consequently of opinion that I was wrong when in 1884 * I said that, "though it may be a matter of regret that it"—the genus now known as *Rhizodus*—"did not retain the name *Megalichthys*, the laws of nomenclature do not admit of any alteration now"; and that Mr O. P. HAY is technically right in wishing to restore that name to the "big fish" of the Scottish Lower Carboniferous period. But the inconvenience which would be caused at the present time by the replacement of *Rhizodus* by *Megalichthys* would be such that I prefer meanwhile to adhere to the current nomenclature.

### Family CŒLACANTHIDÆ.

### Genus *Cœlacanthus*, Agassiz.

*Cœlacanthus*, sp. indet.

Since my preliminary note on the Gullane fishes was written, various fragments of a species of *Cœlacanthus* have occurred in the highest or "Crustacean" bed, but unfortunately none are sufficiently perfect to enable one to refer them to a known species, or to found a new one for their reception. The species must have attained a respectable size for a *Cœlacanthus*, as some of its scales are nearly $\frac{3}{8}$ inch in antero-posterior diameter; their exposed surface is covered with an ornament approximately similar to that in *C. elegans*, Newb. (*lepturus*, Ag.), but to all appearance finer and more delicate. The sculpture of the head bones is not shown in any of the specimens, so that no satisfactory comparison with other species can as yet be obtained.

*Bed c.* Collected by Mr MACCONOCHIE, and also found by Messrs R. DUNLOP and ANGUS PEACH.

* *Geol. Mag.* [3], vol. i., p. 115.

## Order ACTINOPTERYGII.

### Family PALÆONISCIDÆ.

### Genus *Gonatodus*, Traquair.

### *Gonatodus punctatus*, Agassiz, sp. Pl. II. figs. 1, 2.

1835. *Amblypterus punctatus*, Agass., *Poiss. Foss.*, vol. ii. part i. p. 109, pl. iv.*c* fig. 4 (*non* figs. 3, 5–8).
1872. *Amblypterus anconoœchmodus*, R. Walker, *Trans. Edinb. Geol. Soc.*, vol. ii. pt. i. p. 119, with plate.
1877. *Gonatodus punctatus*, R. H. Traquair, *Qu. Journ. Geol. Soc.*, vol. xxxiii. p. 555, and *Proc. Roy. Soc. Edinb.*, vol. ix. p. 265; and Ganoid Fishes Brit. Carb. Form. (*Pal. Soc.*), pl. ii. figs. 4, 5.
1890. *Gonatodus punctatus*, R. H. Traquair, *Proc. Roy. Soc. Edinb.*, vol. xvii. p. 391.
1891. *Gonatodus punctatus*, A. S. Woodward, *Cat. Foss. Fishes Brit. Mus.*, pt. ii. p. 434.

When the preliminary note on these fishes was written in 1904, only one relic of this beautiful Palæoniscid had been found at Gullane, namely, the dentary element of the right ramus of the mandible, showing the characteristic dentition, but subsequently four additional examples were obtained by Mr MACCONOCHIE. These are—two examples of the entire fish; another showing the scales of the anterior part of the body in apposition; while the fourth is the impression of the two rami of the mandible with the branchiostegal rays. Of the two specimens of the entire fish, one (Pl. II. fig. 1) is especially interesting as being the smallest example of the species which I have ever seen, its length being a little over 3 inches and its greatest depth slightly over 1 inch. The other entire specimen is larger, but somewhat distorted in shape. As regards the one showing the flank scales in apposition, with the operculum and some elements of the shoulder girdle, the scales are remarkably smooth and free from striations, but there can be no doubt as to the correctness of the specific determination.

### Genus *Elonichthys*, Giebel.

### *Elonichthys Robisoni*, Hibbert, sp. Pl. I. fig. 1.

1835. *Palæoniscus Robisoni*, Hibbert, *Trans. Roy. Soc. Edinb.*, vol. xiii. p. 191, pl. vi. figs. 6, 7, pl. vii. figs. 1–3.
1835. *Palæoniscus Robisoni*, Agassiz, *Poiss. Foss.*, vol. ii. pt. i. p. 88, pl. x.*a* figs. 1, 2.
1835. *Palæoniscus striolatus*, Agassiz, *ibid.*, p. 91, pl. x.*a* figs. 3, 4.
1835. *Amblypterus nemopterus*, Agassiz, *ibid.*, p. 107, pl. iv.*b* figs. 1, 2.
1835. *Amblypterus punctatus*, Agassiz (*pars*), *ibid.*, p. 109, pl. iv.*c* figs. 3, 5–8.
1835. *Pygopterus Bucklandi*, Agassiz in S. Hibbert, *op. cit.*, p. 217, pl. vii. fig. 2.
1844. *Pygopterus Bucklandi*, Agassiz, *Poiss. Foss.*, vol. ii. pt. ii. p. 77.
1877. *Elonichthys Robisoni*, R. H. Traquair, *Qu. Journ. Geol. Soc.*, vol. xxxiii. p. 553.
1877. *Elonichthys intermedius*, R. H. Traquair, *Proc. Roy. Soc. Edinb.*, vol. ix. p. 279.
1877. *Elonichthys ovatus*, R. H. Traquair, *ibid.*, p. 427.
1877. *Elonichthys nemopterus*, R. H. Traquair, *ibid.*, p. 278, and *Qu. Journ. Geol. Soc.*, vol. xxxiii. p. 553.

1877. *Elonichthys striolatus*, R. H. Traquair, *ibid.*, p. 553, and Ganoid Fishes Brit. Carb. Form. (*Pal. Soc.*), p. 57, pl. vii. figs. 4–15.
1880. *Elonichthys tenuiseratus*, R. H. Traquair, *Proc. Roy. Phys. Soc. Edinb.*, p. 119.
1880. *Elonichthys Dunsii*, R. H. Traquair, *ibid.*, p. 126.
1891. *Elonichthys Robisoni*, A. S. Woodward, *Cat. Foss. Fishes Brit. Mus.*, pt. ii. p. 495.
1891. *Elonichthys Bucklandi*, A. S. Woodward, *ibid.*, p. 497.
1901. *Elonichthys Robisoni*, R. H. Traquair, Gan. Fishes Brit. Carb. Form., pp. 62–70,—including as variations, *striolatus*, *Bucklandi*, *intermedius*, *nemopterus*, *tenuistriatus*, and *Dunsii*.

A considerable number of more or less fragmentary specimens are referable to this species, so common in the estuarine beds of the Lower Carboniferous series in Scotland. Among these, the nearest approach to a complete fish is represented in Pl. I. fig. 1. This example appears to be referable to the variety *nemopterus* (see my Pal. Soc. monograph, 1901, p. 68), characterised by its delicately marked scales and slender fin-rays with distant articulations, but most of the others approach rather more the type of *intermedius* (*op. cit.*, p. 67). But the varieties of *E. Robisoni* all seem to pass insensibly into each other, as is natural in so common a species.

### *Elonichthys striatus*, Agassiz, sp.

1835. *Amblypterus striatus*, Agassiz, *Poiss. Foss.*, vol. ii. pt. i. p. iii., pl. iv.*b* figs. 3–6.
1857. *Rhabdolepis striatus*, Troschel, *Verh. naturh. Verein. preuss.*, Rheinl. und Westfal., p. 16.
1877. *Cosmoptychius striatus*, R. H. Traquair, *Qu. Jour. Geol. Soc.*, vol. xxxiii. p. 553; and Gan. Fishes Brit. Carb. Form. (*Pal. Soc.*), p. 43, pl. ii. fig. 7, pl. iii. figs. 1–8.
1890. *Elonichthys striatus*, R. H. Traquair, *Proc. Roy. Soc. Edinb.*, vol. xvii. pp. 390, 396.
1891. *Elonichthys striatus*, A. S. Woodward, *Cat. Foss. Fishes Brit. Mus.*, pt. ii. p. 491.

This is perhaps the commonest species of fish in this locality, the Survey collection containing a great many specimens, some of which are nearly entire. Most of these are from bed *a*; but its presence in bed *b* has been proved not only by Mr Macconochie, but also by Messrs Bowie and W. T. Gordon.

### *Elonichthys striatulus*, Traquair. Pl. I. figs. 2–5.

1904. *Elonichthys striatulus*, R. H. Traquair, in *Summ. Prog. Geol. Survey* for 1903, p. 121.

The specimen represented in Pl. I. fig. 2, the only one which has hitherto occurred at Gullane, measures a little over 2 inches as it stands, but its original length may be estimated at $2\frac{1}{2}$,* as the tip of the caudal extremity and also of the snout are both cut off by the edges of the stone. The length of the head would probably be to the total as one in four; its roof-bones are ornamented by comparatively coarse and distant ridges, with some tubercles on the parietal region; the external sculpture seen on the facial bones and on the elements of the shoulder girdle consists also of ridges of

* In the diagnosis of this species given in the *Summary of Progress* a strange misprint occurs, "21" inches being given as the estimated length of the specimen instead of "$2\frac{1}{2}$."

a similar character to those on the cranial roof. The scales of the flank (fig. 3) are ornamented with fine yet well-marked ridges, which pass across the exposed surface from front to back in a direction mainly parallel with the upper and lower margins; in many cases the ridge is double, the two divisions uniting close to the posterior margin of the scale; in the caudal region (fig. 4) the ridges become more oblique in their direction. Several large azygous scales occur in front of the dorsal fin. This fin, situated about the middle of the back, is proportionally large, its rays are very slender, and with unusually distant articulations; the joints are marked occasionally with a very delicate longitudinal furrow, or it may be with two; the form of the fin would be triangular acuminate were not the apical portion largely cut off by the edge of the stone. The anal fin is lost; the caudal is heterocercal, inequilobate, deeply cleft, and with distantly articulated slender rays similar to those of the dorsal; fin-fulcra few and very oblique. Paired fins not preserved.

On looking over some undetermined Eskdale material in the collection of the Royal Scottish Museum, I found a small fish from Glencartholm which is certainly specifically identifiable with the above-described example from Gullane, and which is represented in Pl. I. fig. 5. It is slightly larger, as it measures nearly 3 inches in length, and is more perfect, inasmuch as its contour is seen from the tip of the snout to the termination of the upper lobe of the tail-fin. The length of the head is contained about four times in the total; its superficial bones are sculptured, as in the Gullane specimen, with comparatively coarse and distant ridges, and the form and ornament of the scales is also the same. As in the above-described specimen, the paired fins are not shown, while, in addition, the dorsal is wanting; on the other hand, the anal is present and the caudal is complete. We have again the same character of the fin-rays,—as before, they are very slender and very distantly articulated, while the fulcra in front of the anal and caudal are few, elongated, and oblique.

I have placed this little fish in the genus *Elonichthys* on account of its general aspect and the form and position of the unpaired fins, though the condition of the fin-fulcra deviates considerably from that which is usual in the genus. In all its details it is strikingly distinct from every other known species.

The specimen, Pl. II. fig. 2, collected by Mr Macconochie at Gullane, is from bed *a*.

## Genus *Rhadinichthys*, Traquair.

### *Rhadinichthys ornatissimus*, Agassiz, sp.

1835. *Palæoniscus ornatissimus*, Agassiz, *Poiss. Foss.*, vol. ii. pt. i. p. 92, pl. x.*a* figs. 6, 8 (*non* figs. 5, 7).
1877. *Rhadinichthys ornatissimus*, R. H. Traquair, *Qu. Journ. Geol. Soc.*, vol. xxxiii. p. 559, and *Proc. Roy. Soc. Edinb.*, vol. ix. p. 432.
1877. *Rhadinichthys lepturus*, R. H. Traquair, *Proc. Roy. Soc. Edinb.*, vol. ix. p. 437.
1890. *Rhadinichthys ornatissimus*, R. H. Traquair, *Proc. Roy. Soc. Edinb.*, vol. xvii. pp. 391, 397.
1891. *Rhadinichthys ornatissimus*, A. S. Woodward, *Cat. Foss. Fishes Brit. Mus.*, pt. ii. p. 462.

One fragmentary specimen has occurred, showing the head with a portion of the front of the body, the scales of which are considerably mashed up together. However, what can be seen of the ornamentation of these scales, along with the impressions of the bones of the head, shows conclusively with what species we have to deal.

Collected by Mr Macconochie in bed *a*.

### *Rhadinichthys brevis*, Traquair. Pl. II. figs. 3–5.

1877. *Rhadinichthys brevis*, R. H. Traquair, *Proc. Roy. Soc. Edinb.*, vol. ix. p. 440.
1891. *Rhadinichthys brevis*, A. S. Woodward, *Cat. Foss. Fishes Brit. Mus.*, pt. ii. p. 462.
1901. *Rhadinichthys brevis*, R. H. Traquair, *Geol. Mag.* (4), vol. viii. p. 111.

In the remarks appended to my original description of the species from the beds at Wardie, I compared it specially with *Rh. Geikiei*, Traq., from Colinton. But as I have since then adopted the view that *Rh. Geikiei* represents but a young stage of *Rh. carinatus*, Agassiz, it is with the adult of the last-named species that the comparison must be carried out. Compared, then, with *R. carinatus*, *Rh. brevis* is, as the name implies, proportionally shorter, the unpaired fins are larger, the distance between the commencement of the anal and that of the caudal is proportionally smaller, the ridges on the cranial roof-bones are coarser, though in this latter respect there is some variation in *Rh. brevis*. It is undoubtedly a good species, and occurs not only at the original locality, Wardie, and here, at Gullane, but also in Fifeshire (*Geol. Mag.*, *t. cit. ant.*, p. 111).

Collected by Mr Macconochie from bed *a*;—a slightly doubtful specimen has also been obtained by Mr W. T. Gordon in bed *b*.

### *Rhadinichthys elegantulus*, Traquair.

1881. *Rhadinichthys Geikiei*, R. H. Traquair, *Trans. Roy. Soc. Edinb.*, vol. xxx. p. 25, pl. i. figs. 13–18.
1881. *Rhadinichthys Geikiei*, var. *elegantulus*, R. H. Traquair, *ibid.*, p. 27, pl. ii. figs. 1–5.
1881. *Rhadinichthys delicatulus*, R. H. Traquair, *ibid.*, p. 29, pl. ii. figs. 6–9.
1890. *Rhadinichthys elegantulus* (with var. *delicatulus*), R. H. Traquair, *Proc. Roy. Soc. Edinb.*, vol. xvii. p. 398.
1891. *Rhadinichthys elegantulus*, A. S. Woodward, *Cat. Foss. Fishes Brit. Mus.*, pt. ii. p. 464.

To this species I refer a small and not quite perfect specimen collected by Mr Macconochie in bed *a*. I certainly cannot distinguish it from the Glencartholm fish whose synonymy is given above.

### *Rhadinichthys formosus*, Traquair. Pl. I. fig. 6, Pl. II. figs. 6–8

1904. *Rhadinichthys formosus*, R. H. Traquair, in *Summary of Progress Geol. Survey* for 1903, p. 122.

The original specimen of this form is represented in Pl. II. fig. 6; unfortunately it is not perfect, as nearly the whole of the upper and a great portion of the lower lobe of the caudal fin is lost. As it is, the length is $3\frac{3}{4}$ inches; but when entire the fish

must have measured 4½ inches. The length of the head is contained three and a half times in the distance from the tip of the snout to the commencement of the lower lobe of the caudal fin, and is equal to the greater depth of the body between the dorsal fin and the occiput. The cranial roof-bones are marked with fine contorted and interrupted striæ, and a striated ornament characterises also the facial bones, namely, the maxilla, mandible, and branchiostegal rays. The dorsal fin is situated behind the arch of the back, and more than twice the length of the head from the end of the snout; the anal commences a little further back; both fins are large, triangular-acuminate, with many slender rays which are distantly articulated, the joints being often marked with a delicate furrow close to, and parallel with, the posterior margin. The fulcra in both fins are very well marked. The caudal is, as already indicated, broken off near its commencement; indications both of pectoral and ventral rays are seen at their proper places, but the fins themselves cannot be described. The scales are moderate in size, those on the flank showing an ornament which to some extent resembles that of the scales of *Elonichthys pulcherrimus* from the Glencartholm beds, the exposed surface being covered with closely-set fine ridges, those on the posterior-superior part passing obliquely downwards and backwards, while on the anterior-inferior aspect they pass nearly horizontally backwards, and parallel to the inferior margin. On the hinder border of each scale these ridges end in delicate denticulations. As regards the scales posterior to the region of the ventral fins, the ornament tends to become less pronounced, and reduced to a set of grooves passing obliquely across the surface from front to back, but the scales along the origin of the anal fin, and also of the dorsal, as seen in the counterpart, are strongly ridged. All over the body the scales are singularly undisturbed, so that the proportions of the fish are accurately shown.

In Pl. I. fig. 6 is represented another specimen, which, according to its scale ornamentation and other details, I identify specifically with the one described above. Its proportions seem, however, at first sight, rather different, the dorsal fin appearing relatively further forward, the caudal disproportionately large, while the depth of the body at the shoulder is considerably greater than the apparent length of the head. But, on a careful examination of the specimen, it is evident that these appearances are due to distortion by "shortening up," the scales of the region behind the head being confused, so that the body at this place is, as it were, "telescoped." The specimen measures 4½ inches in length, but I should add on at least one more inch to express its original dimensions, so that we have now before us a larger example than the previous one. I figure this specimen on account of the perfect caudal extremity which it displays. The fin is deeply cleft and inequilobate, the prolongation of the body axis along the upper lobe being proportionately stronger than in the type species of the genus (*Rh. ornatissimus*).

Still another specimen exists in the Survey Collection, but less perfect than either of the two examples described above. It is also shortened up in a manner somewhat similar to that noticed in the second one.

I have placed this species in *Rhadinichthys* owing to its resemblance in external form to *Rh. brevis*, although the condition of the pectoral fin cannot be ascertained.

From bed *a*, collected by Mr Macconochie, and also by myself.

### *Nematoptychius Greenocki*, Agassiz sp.

1844. *Pygopterus Greenockii*, Agassiz, *Poiss. Foss.*, vol. ii. pt. ii. p. 78 (undefined).
1867. *Pygopterus Greenockii*, R. H. Traquair, *Trans. Roy. Soc. Edinb.*, vol. xxiv. p. 701, pl. xlv. figs. 1–7.
1872. *Pygopterus elegans*, C. W. Peach, *Rep. Brit. Assoc.*, 1871, Trans. Sect., p. 109 (name only).
1875. *Nematoptychius Greenockii*, R. H. Traquair, *Ann. Mag. Nat. Hist.* (4), vol. xv. p. 258, pl. xvi. figs. 7–11.
1877. *Nematoptychius gracilis*, R. H. Traquair, *Proc. Roy. Soc. Edinb.*, vol. ix. p. 262 (=young form of *N. Greenockii*).
1877. *Nematoptychius Greenockii*, R. H. Traquair, *Qu. Journ. Geol. Soc.*, vol. xxxiii. p. 577, and Ganoid Fishes Brit. Carb. Form. (*Pal. Soc.*), pl. i. figs. 7–11.
1890. *Nematoptychius Greenocki*, R. H. Traquair, *Proc. Roy Soc. Edinb.*, vol. xvii. pp. 391, 398.
1891. *Nematoptychius Greenocki*, A. S. Woodward, *Cat. Foss. Fishes Brit. Mus.*, pt. ii. p. 458.

Fragmentary specimens of this interesting Palæoniscid, so extensively distributed in the Lower Carboniferous rocks of the East of Scotland, have been found in Bed *b*, both by Mr Macconochie and by Mr W. T. Gordon.

## Family Platysomidæ.

### Genus *Wardichthys*, Traquair.

### *Wardichthys cyclosoma*, Traquair. Pl. II. fig. 9.

1875. *Wardichthys cyclosoma*, R. H. Traquair, *Ann. Mag. Nat. Hist.* (4), vol. xv. p. 262, pl. xvi. figs. 1–5.
1879. *Wardichthys cyclosoma*, R. H. Traquair, *Trans. Roy. Soc. Edinb.*, vol. xxix. p. 361, pl. iv. figs. 12–15.
1881. *Wardichthys cyclosoma*, T. Stock, *Ann. Mag. Nat. Hist.* (5), vol. vii. p. 490.
1891. *Wardichthys cyclosoma*, A. S. Woodward, *Cat. Foss. Fishes Brit. Mus.*, pt. ii. p. 535.

The genus *Wardichthys*, with the single species *cyclosoma*, was instituted by me in 1875 for a small Platysomid fish from the Lower Carboniferous shales, exposed at Wardie beach, near Edinburgh. Only a single specimen was then known, and of this I gave a minute description in the *Annals and Magazine of Natural History* for April of the year named. Again, in my Essay on the "Structure and Affinities of the Platysomidæ," published in the *Transactions of the Royal Society of Edinburgh* for 1879, I recapitulated the principal characters of the genus, and showed that of all the generic forms of Platysomidæ it was most nearly allied to *Mesolepis*.

The original specimen showed the general shape of the body and the character of the squamation, some of the osteological details of the head, the dorsal fin, and a few traces of the anal. Another specimen, subsequently obtained by the late Mr T. Stock, and of which the counterpart is now in the Royal Scottish Museum, shows distinctly the pectoral and ventral fins, but only traces of the anal, while the caudal is again wholly wanting, having been cut off by the edge of the ironstone nodule in which the fish is contained.

But quite a number of specimens of *Wardichthys cyclosoma* have turned up at Gullane, and in several of these the caudal as well as the anal fin is well shown, so that now the material has been obtained on which to construct the restored figure, which I herewith append. The generic diagnosis may also be amended as follows:—

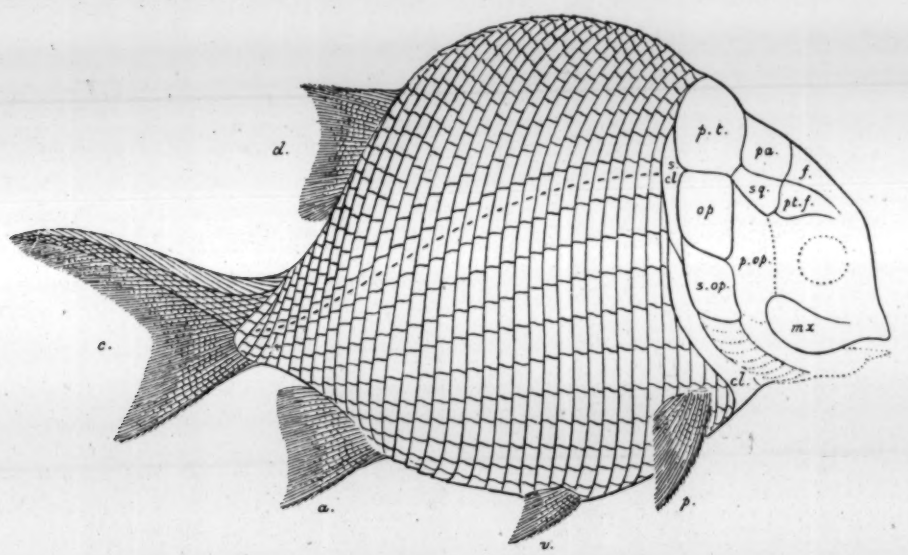


Fig. 1.—Restored outline of *Wardichthys cyclosoma*, Traquair. *pa.*, parietal; *f.*, frontal; *sq.*, squamosal; *pt.f.*, post-frontal; *op.*, operculum; *s.op.*, suboperculum; *mx.*, maxilla; *p.t.*, post-temporal; *s.cl.*, supraclavicular; *cl.*, clavicle; *p.*, pectoral; *v.*, ventral; *d.*, dorsal; *a.*, anal; *c.*, caudal.

Genus *Wardichthys*, Traquair. Body deep, nearly circular in profile; ventral fins present, situated nearly exactly between the pectorals and the anal. Dorsal fin small, arising considerably behind the top of the rounded arch of the back, and terminating near the commencement of the tail pedicle; its base somewhat extended in proportion to its height. Anal, placed a little further back than the dorsal, short based, triangular-acuminate in form. Caudal comparatively small, heterocercal, deeply cleft. All the fins with distinct fulcra; their rays closely set and closely articulated. Cranial osteology allied to that of *Mesolepis*, but the dentition is still unknown. Scales of the middle of the flank high and narrow, more equilateral behind and towards the dorsal and ventral margins; covered area broad, exposed surface ornamented by a close tuberculation, the tubercles often coalescing into short ridges; azygous scales in front of the dorsal and anal fins, with well-marked backwardly-directed spur-shaped points. Only species, *W. cyclosoma*, Traq.

The new points here brought out are—the presence of pectorals and ventrals, and the contour of the anal and caudal fins. Though the dentition is still unknown, the affinity of the genus to *Mesolepis* is obvious, as already remarked in my paper on the Platysomidæ, but the small size of the dorsal fin and its backward position are marks of sufficient importance to justify the validity of *Wardichthys*.

For purposes of comparison I add a restored outline of *Mesolepis*, of which only the head part has been previously published in my paper on the Structure and Affinities of the Platysomidæ.

All the specimens from the Gullane locality in the Survey Collection are from bed *a*, and represent fishes from 2 to 4 inches in length. From bed *c* (the "crustacean" bed) Mr F. H. Butler, of London, obtained a nearly perfect specimen, now in

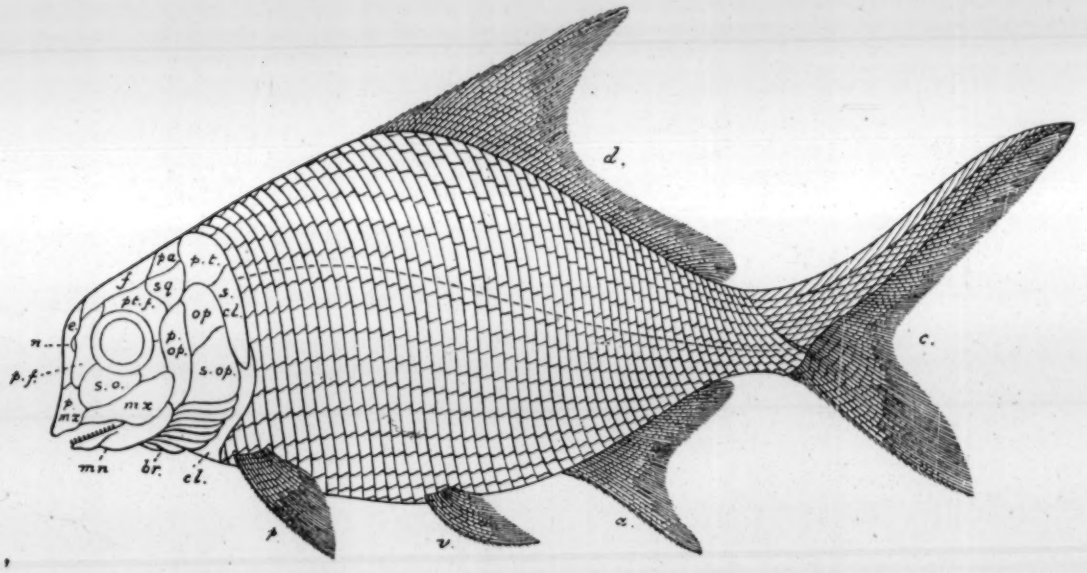


Fig. 2.—Restored outline of *Mesolepis scalaris*, Young, from the North Staffordshire Coalfield. *e.*, dermal ethmoid; *n.*, nasal opening; *p.f.*, pre-frontal; *p.op.*, preoperculum; *s.o.*, suborbital; *mn.*, mandible; *p.mx.*, premaxilla. Other lettering as in fig. 1.

the British Museum. I am indebted to Dr A. S. Woodward for the privilege of examining this specimen, the largest which I have seen, as it measures a fraction over 5 inches in length.

## Conclusion.

Having now gone over, from a zoological standpoint, the fishes collected at this interesting locality, it remains for me to say a few words regarding their interest to the geologist.

It is, of course, for the officers of the Geological Survey to settle the horizon of these fish-bearing beds by correlating the various lights thrown on them by stratigraphy as well as by palæontology, and here it must also be remembered that they contain other fossils besides fishes. Nevertheless, it may be permitted to me to point out the

result of a comparison of this fish-fauna with that of other localities in Scotland in which estuarine fishes of Lower Carboniferous age occur.

First of all, we may give a complete list of the fishes which have hitherto been found at this locality, indicating also the respective beds in which they have occurred.

| | Bed *a*. | Bed *b*. | Bed *c*. |
|---|---|---|---|
| *Acanthodes*, sp., | × | — | — |
| *Rhizodus Hibberti*, | × | × | — |
| *Cœlacanthus*, sp., | — | — | × |
| *Gonatodus punctatus*, | × | — | — |
| *Elonichthys Robisoni*, | × | — | — |
| ,, *striatus*, | × | × | — |
| ,, *striatulus*, | × | — | — |
| *Rhadinichthys ornatissimus*, | × | — | — |
| ,, *brevis*, | × | × | — |
| ,, *elegantulus*, | × | — | — |
| ,, *formosus*, | × | — | — |
| *Nematoptychius Greenocki*, | — | × | — |
| *Wardichthys cyclosoma*, | × | — | × |

Here I may first draw attention to the fact that the list contains no representative of the Elasmobranchii, with the exception of the peculiar group of Acanthodei.

Then I need hardly point out that the assemblage is one of Lower Carboniferous estuarine forms. Not one of the named species can be noted as indicating an Upper Carboniferous horizon.

Among those named species we are struck with the presence of one rare form—*Wardichthys cyclosoma*—hitherto found with certainty only in one locality, and that locality is Wardie, near Granton, from which a division of the Calciferous Sandstone series of the Edinburgh district, namely, the Wardie Shales, takes its name.

In my paper "On the Distribution of Fossil Fish-remains in the Carboniferous Rocks of the Edinburgh District,"* I have given a list of the fossil fishes of Wardie beach, which I reproduce here :—

*Pleuracanthus*, sp.
*Acanthodes sulcatus.*
*Megalichthys*, sp.
*Rhizodus Hibberti.*
*Gonatodus punctatus.*
*Elonichthys Robisoni.*
,, *striatus.*
*Rhadinichthys ornatissimus.*
,, *carinatus.*
,, *brevis.*
,, *ferox.*
*Nematoptychius Greenocki.*
*Eurynotus crenatus.*
*Wardichthys cyclosoma.*

Here we find that, in this list of fourteen species, eight out of the thirteen from

* *Trans. Roy. Soc. Edinb.*, vol. xl., pt. iii., No. 28, p. 690.

Gullane are repeated, namely, *Rhizodus Hibberti*, *Gonatodus punctatus*, *Elonichthys Robisoni*, *E. striatus*, *Rhadinichthys ornatissimus*, *Rh. brevis*, *Nematoptychius Greenocki*, and *Wardichthys cyclosoma*. And of these eight species, four, namely, *Gonatodus punctatus*, *Elonichthys Robisoni*, *Elonichthys striatus*, and *Nematoptychius Greenocki*, are the commonest of all the fishes which are to be found in the Wardie nodules.

I now give a second table showing the proportion of the specifically determined Gullane fishes represented in Lower Carboniferous estuarine rocks of the Edinburgh district belonging to higher horizons than the Wardie Shales.

| Named Species from Gullane. | Wardie Shales. | Burdiehouse Limestone. | Dunnet Shale. | Lower Limestone Group. | Edge Coals. | Upper Limestone Group. |
|---|---|---|---|---|---|---|
| *Rhizodus Hibberti*, | × | × | — | × | × | × |
| *Gonatodus punctatus*, | × | ? | — | — | — | — |
| *Elonichthys Robisoni*, | × | × | × | × | × | — |
| ,, *striatus*, | × | × | × | — | — | — |
| ,, *striatulus*, | — | — | — | — | — | — |
| *Rhadinichthys ornatissimus*, | × | × | × | — | × | — |
| ,, *brevis*, | × | — | — | — | — | — |
| ,, *elegantulus*, | — | — | — | — | — | — |
| ,, *formosus*, | — | — | — | — | — | — |
| *Nematoptychius Greenocki*, | × | × | × | × | × | × |
| *Wardichthys cyclosoma*, | × | — | — | — | — | — |
| 11 | 8 | 5 | 4 | 3 | 4 | 2 |

From this table, that of the eleven named species found in the Gullane beds,—

*Eight* occur in the Wardie Shales.

*Five* in the Burdiehouse Limestone.

*Four* in the Oil Shales between the Burdiehouse Limestone and the Lower Marine Limestone series.

*Three* in the Lower Limestone series.

*Four* in the Edge Coal series.

*Two* in the Upper Limestone series.

Or, to express the matter in different words, while nearly four-fifths of the named Gullane species are represented at Wardie, these species become fewer and fewer as we proceed upwards in the Lower Carboniferous of the district, till in the Upper Limestone series only two, or less than one-fifth, has as yet been met with.

In my paper already quoted, I have remarked (p. 698) "that it is scarcely possible to mark out satisfactory zones by means of the fishes, so far as the Lower Carboniferous rocks are concerned"; but I have also qualified this statement by another, namely, that "some amount of difference there is between the lists from the top and from the

bottom of the fish-bearing series" (p. 701). And I have shown that while some species like *Nematoptychius Greenocki* and *Eurynotus crenatus* persist from bottom to top of these estuarine fish-bearing rocks, some have as yet only occurred in the lower, others in the upper, horizons as usually adopted.

If, then, fish-remains are to count in the determination of the horizon of the Gullane beds, I would point out that their fish-fauna show the greatest amount of agreement with that of the Wardie Shales of all the horizons in the Lower Carboniferous of Central Scotland in which fishes have been found.

Finally, we have seen that out of eleven named Gullane species, eight occur at Wardie. What of the other three, which have not been found in any other locality near Edinburgh?

Of these, one is peculiar to the East Lothian locality, namely, *Rhadinichthys formosus.*

The remaining two, namely, *Elonichthys striatulus* and *Rhadinichthys elegantulus*, form part of the peculiar Lower Carboniferous fish-fauna of Glencartholm, on the River Esk, near Langholm. Two explanations of the peculiarity of this fish-fauna have been suggested,—either the existence of a land barrier, or a difference in horizon, these Eskdale beds being supposed to be of older date than the Granton and Craigleith Sandstones. The latter explanation does not seem probable in the face of the fact that such well-known Central Scottish species as *Oracanthus armigerus*, Traq., and *Tristychius minor*, Portl., have also been found at Glencartholm, while the determination of two further species as common to the last-named locality and Gullane is further evidence against the idea, so far as fishes are concerned. If, however, the existence of a land barrier was the cause of the phenomenon in question, it is clear that it was not sufficient to prevent the intermixture of species to a certain extent. The Glencartholm beds were certainly not deposited in a land-locked lake at all events, as the occurrence of numerous marine shells in them amply testifies. The further development of the subject I must leave to the Officers of the Geological Survey.

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## EXPLANATION OF THE PLATES.

[All the figures are taken from specimens from Bed *a*, Gullane, except fig. 5 on Plate I., which illustrates a specimen from Glencartholm, near Langholm, Eskdale.]

### Plate I.

Fig. 1. *Elonichthys Robisoni* (Hibbert). Natural size. Gullane. (*Geol. Surv. Scot.*, M 293 f.)

Fig. 2. *Elonichthys striatulus*, Traq. Natural size. Same locality. (*Geol. Surv. Scot.*, M 4409 E.)

Fig. 3. Flank scales of the above specimen, magnified 12 diameters.

Fig. 4. Caudal scale from the same, magnified 12 diameters.

Fig. 5. *Elonichthys striatulus*, Traq. Natural size. From Glencartholm, Eskdale, in the Royal Scottish Museum.

Fig. 6. *Rhadinichthys formosus*, Traq., distorted by "shortening up" of the anterior part of the body. Natural size. Gullane. (*Geol. Surv. Scot.*, M 292 f.)

PLATE II.

Fig. 1. *Gonatodus punctatus* (Agassiz). Young specimen; natural size. Gullane. (*Geol. Surv. Scot.*, M 297 f.)

Fig. 2. Inner surface of the dentary element of the mandible of an adult specimen of *Gonatodus punctatus*, magnified 2 diameters. Some scales are scattered over the proximal extremity of the bone, and the teeth are considerably obscured by matrix. Same locality. (*Geol. Surv. Scot.*, M 4437 E.)

Fig. 3. *Rhadinichthys brevis*, Traq. Natural size. Same locality. (*Geol. Surv. Scot.*, M 4411 E.)

Fig. 4. Another specimen of *Rh. brevis*. Natural size. Same locality. (*Geol. Surv. Scot.*, M 296 f.)

Fig. 5. Flank scales of *Rh. brevis* from another specimen, magnified 8 diameters. Same locality.

Fig. 6. *Rhadinichthys formosus*, Traq. Natural size. Same locality. (*Geol. Surv. Scot.*, M 4418 E.)

Fig. 7. Scale from the flank of the same specimen, magnified 6 diameters.

Fig. 8. Scale from the caudal region of the same specimen, magnified 6 diameters.

Fig. 9. *Wardichthys cyclosoma*, Traq. Natural size. Same locality. (*Geol. Surv. Scot.*, M 4384 E.)

DR R.H. TRAQUAIR ON FOSSIL FISHES FROM GULLANE, PLATE I.

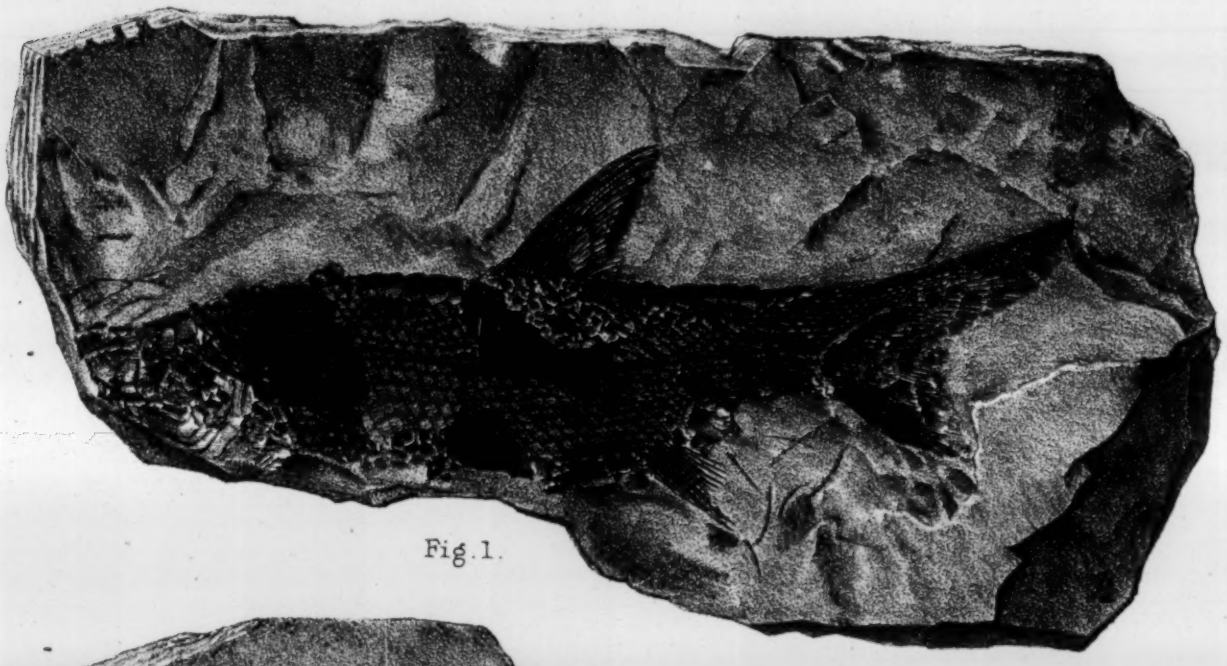

Fig. 1.

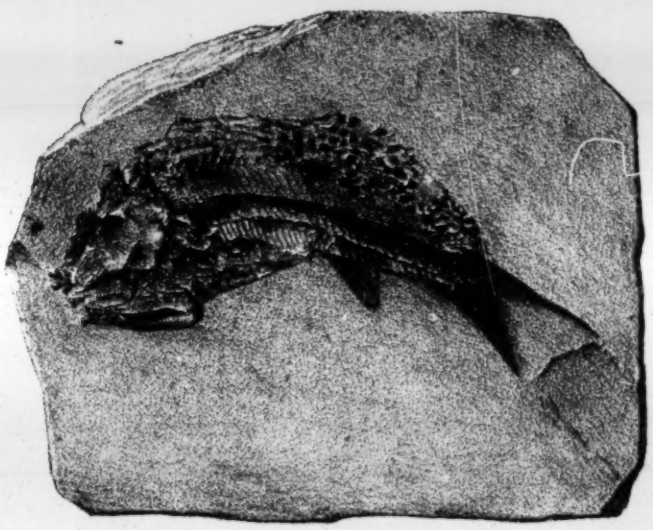

Fig. 5.

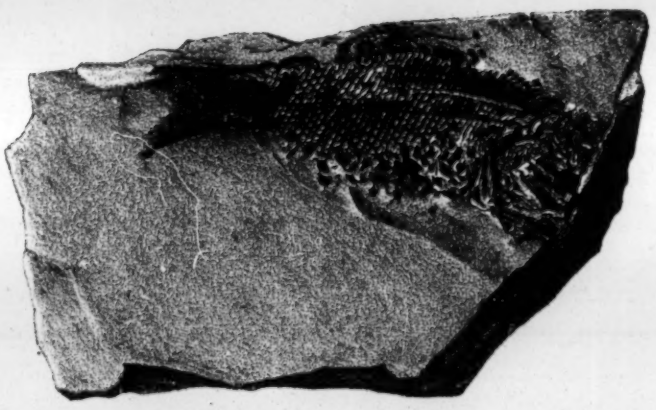

Fig. 2.

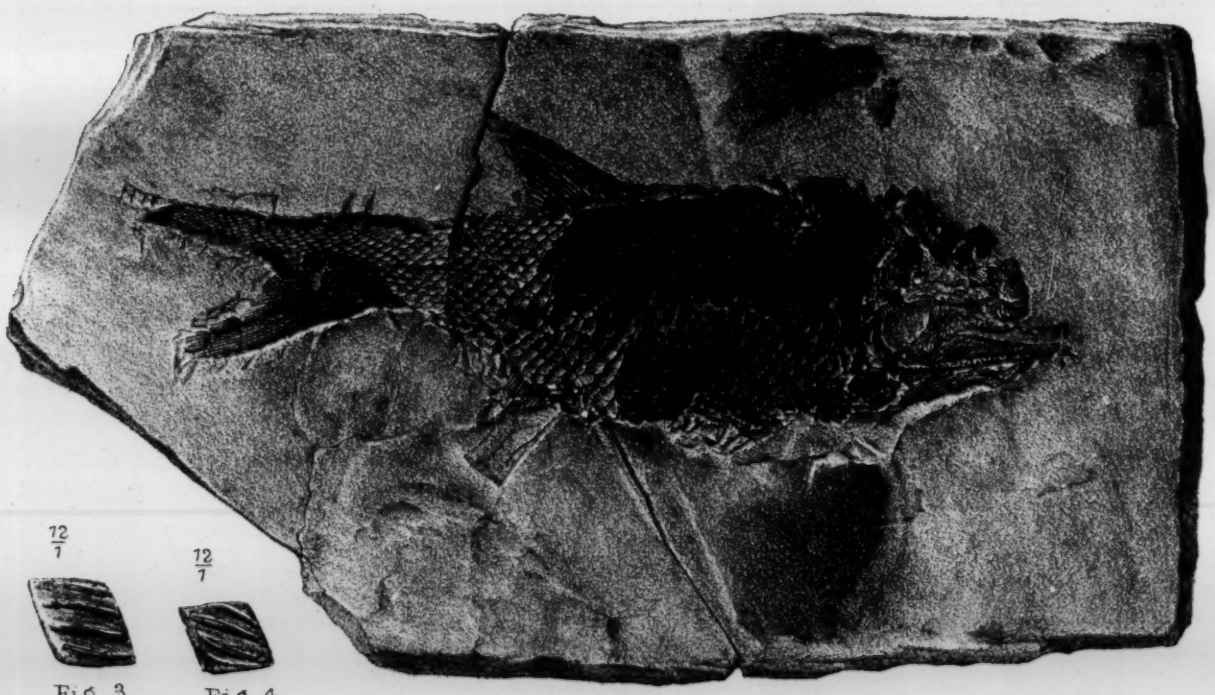




Fig. 3.




Fig. 4.

Fig. 6.

Figs. 1, 2, 5, 6, J. Green.
Figs. 3, 4, R.H. Traquair.

J. Green in lap.

DR R. H. TRAQUAIR ON FOSSIL FISHES FROM GULLANE, PLATE II.

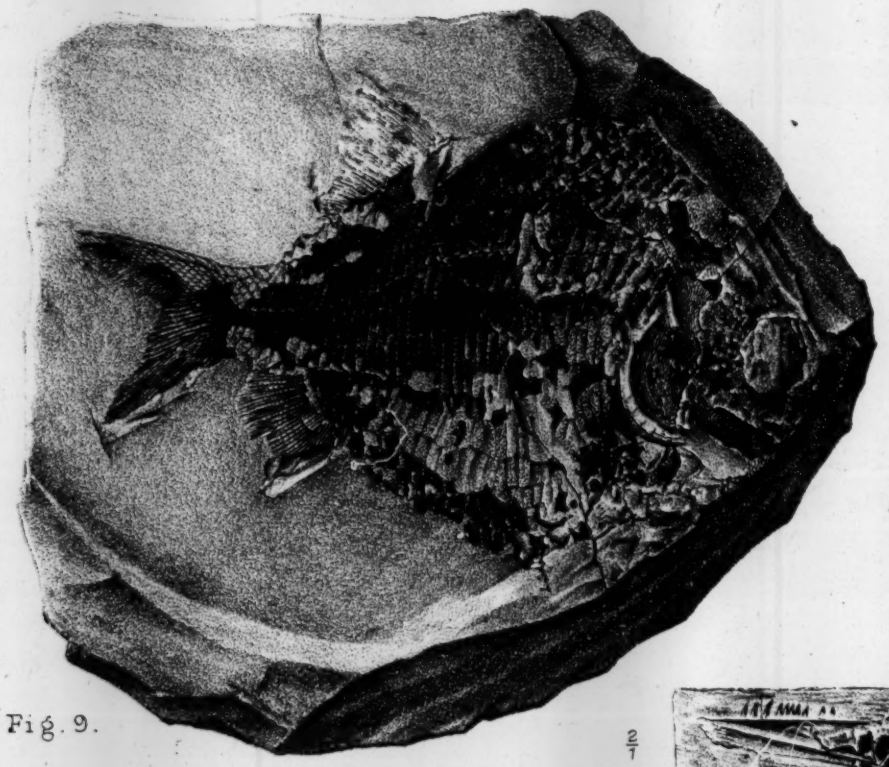

Fig. 9.

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Fig. 2.

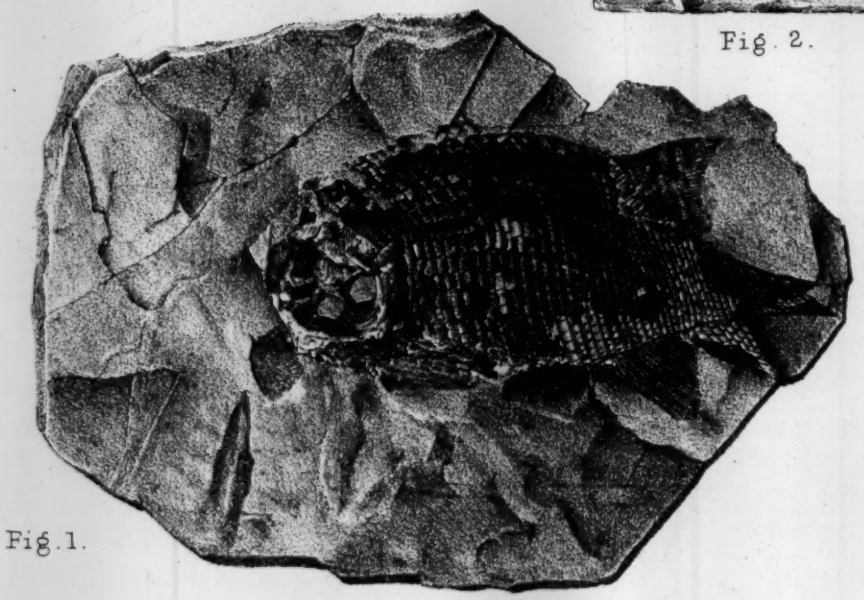

Fig. 1.

Fig. 6.

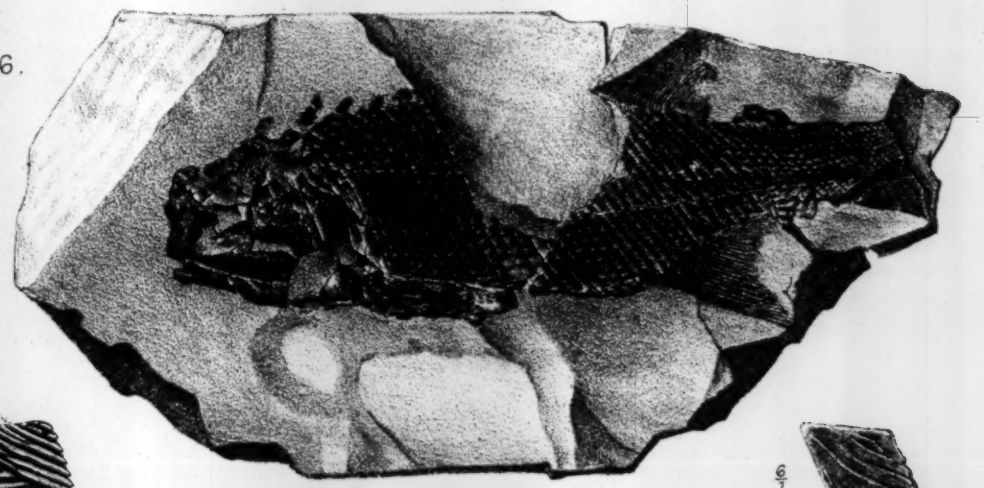

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Fig. 7.

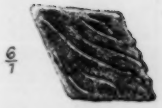

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Fig. 8.

Fig. 3.

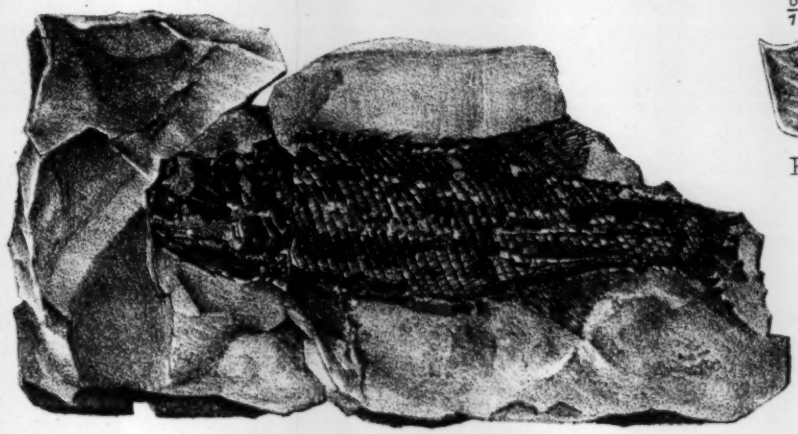

Fig. 4.

8/7

Fig. 5.

# V.—The Marine Mollusca of the Scottish National Antarctic Expedition.

By **James Cosmo Melvill**, M.A., F.L.S., F.Z.S., and **Robert Standen**, Assistant Keeper, Manchester Museum. *Communicated by* Professor J. C. Ewart, F.R.S. (With a Plate.)

(MS. received July 5, 1907. Read July 15, 1907. Issued separately December 21, 1907.)

The marine Mollusca obtained during the Scottish National Antarctic Expedition of s.s. *Scotia* are particularly interesting, not merely on account of certain benthal forms having been for the first time brought to light from unusual depths, but also as demonstrating an extended geographical range for certain meridional species already known; while the occurrence of sundry British and North European individuals in the Falkland Islands—perhaps brought there adventitiously—is, to some extent, a new feature in the fauna. Regarding the deep-sea species just alluded to, the dredging of a second example of the hitherto unique *Guivillea alabastrina*, Watson, from a station not far from the original *Challenger* locality, is very noteworthy; while we may at the same time signalise a *Columbarium*, *Cuspidaria*, *Chrysodomus*, and *Dentalium*, from 1775, 2645, 1775, and 1410 fathoms respectively.

The attention of the scientific world has for some years become more and more centred upon the Arctic and Antarctic polar regions, and, of them, the latter till lately presented the most virgin field for research, both physical, geographical, and biological. Every year fresh expeditions seem to be planned, equipped, and launched for the purpose of critical investigation and exploration, with most beneficial results; and the day may not now be far distant when it will be possible to draw up monographs of the various zoological groups of the Antarctic area, including, we hope, one of the Mollusca. In the meantime, we give below a collated bibliographical *résumé* of the majority of the treatises published on the subject during the past thirty years.

In conclusion, we would express our obligations primarily to Mr Edgar A. Smith, I.S.O., of the British Museum (Nat. Hist.), who has, with us, examined every critical species in the collection. To Mr Ernest R. Sykes, F.L.S., and Dr W. E. Hoyle, F.R.S.E., we are also indebted for the loan of various books and pamphlets bearing upon the subject. To Dr Georg Pfeffer and Dr Hermann Strebel, of Hamburg, our thanks are due for reporting on several forms submitted to them, two of which, obtained likewise by the Swedish South Polar Expedition, and differentiated, but not yet published, by Dr Strebel, we have been asked by him to describe at the present opportunity.

And last, but by no means least, we are most grateful to Mr W. S. Bruce, F.R.S.E., for having entrusted his Molluscan collections to us, and for much kind assistance in the way of maps and general information.

## LIST OF SPECIES CONTAINED IN THE "SCOTIA" COLLECTIONS.

### A. Regio Antarctica—including Gough Island.

#### Class GASTEROPODA.

##### Order Amphineura.

##### Sub-order polyplacophora.

*Callochiton illuminatus* (Reeve)
*Tonicia atrata* (Sowb.).

##### Order Prosobranchiata.

##### Sub-order diotocardia.

###### Family *Acmæidæ*.

*Acmæa ceciliana*, Orbigny.

###### Family *Patellidæ*.

*Patella ænea*, Martyn, var. *deaurata*, Gmel.
„ *fuegiensis*, Reeve.
„ *polaris*, Hombr. and Jacq.

###### Section **Zygobranchiata**.

###### Family *Fissurellidæ*.

*Fissurella oriens*, Sow.
„ *picta*, Gmel.
*Tugalia antarctica*, sp. n.

###### Section **Azygobranchiata**.

###### Family *Trochidæ*.

*Photinula expansa* (Sow.).
„ *tæniata* (Wood).
„ *violacea* (King).
*Valvatella antarctica* (E. Lamy).

##### Sub-order monotocardia.

###### Section (*a*) **Ptenoglossa**.

###### Family *Ianthinidæ*.

*Ianthina exigua*, Lamarck.

Section (*b*) **Tænioglossa.**

Family *Naticidæ.*

*Natica* (*Lunatia*), sp.

Family *Capulidæ.*

*Calyptræa costellata*, Phil.
*Crepidula dilatata*, Lamk.

Family *Littorinidæ.*

*Littorina* (*Lævilitorina*) *caliginosa* (Gould).
,, ,, *coriacea*, sp. n.
,, (*Pellilitorina*) *pellita*, v. Marts.
,, ,, *setosa* (Smith).
*Lacuna divaricata*, Fabr.
,, *notorcadensis*, sp. n.

Family *Rissoidæ.*

*Rissoa adarensis*, Smith.
,, (*Cingula*) *cingillus* (Mont.).
,, *edgariana*, sp. n.
,, *fraudulenta*, Smith.
,, *parva* (Da Costa).
,, (*Onoba*) *scotiana*, sp. n.
,, (*Manzonia*) *zetlandica* (Mont.).
*Eatoniella kerguelensis*, Smith.

Family *Litiopidæ.*

*Litiopa melanostoma*, Rang.

Family *Cerithidæ.*

*Cerithium georgianum*, Pfeffer.
,, *pullum*, Phil.
*Cerithiopsis malvinarum* (Strebel, MS.), sp. n.

Family *Tritonidæ.*

*Gyrineum vexillum* (Sow.).

Section (*c*) **Gymnoglossa.**

Nil.

Section (*d*) **Rachiglossa.**

Family *Muricidæ.*

*Trophon brucei*, Streb.
„ *cinguliferus*, Pfeffer.
„ *crispus* (Couth.).
„ *geversianus* (Pallas).
„ *hoylei*, Streb.
„ *liratus* (Couth.).
„ *minutus* (Strebel, MS.), sp. n.
„ *philippianus*, Dunker.

Family *Nassidæ.*

*Nassa* (*Ilyanassa*) *vallentini*, sp. n.

Family *Buccinidæ.*

*Chrysodomus* (*Sipho*) *archibenthalis*, sp. n.
„ „ *crassicostatus*, sp. n.
*Neobuccinum eatoni* (Smith).
*Euthria fuscata* (Brug.).
„ *magellanica* (Philippi).
„ *michaelseni*, Streb.

Family *Volutidæ.*

*Voluta* (*Cymbiola*) *ancilla* (Sol.).
*Guivillea alabastrina*, Watson.

Section (*e*) **Toxoglossa.**

Family *Conidæ.*

*Columbarium benthocallis*, sp. n.
*Mangilia costata* (Donovan).

Family *Cancellariidæ.*

*Admete magellanica*, Strebel.

Order OPISTHOBRANCHIATA.

Sub-order TECTIBRANCHIATA.

Family *Tornatinidæ.*

*Retusa truncatula* (Brug.).

Section **Siphonarioidea.**

Family *Siphonariidæ.*

*Siphonaria redimiculum*, Reeve.

Order PULMONATA.

Sub-order BASOMMATOPHORA.

Family *Auriculidæ.*

*Marinula nigra*, Phil.

Class SCAPHOPODA.

*Dentalium eupatrides*, sp. n.
,, *shoplandi*, Jouss.

Class PELECYPODA.

Order PROTOBRANCHIATA.

Family *Nuculidæ.*

*Nucula minuscula*, Pfeffer.
*Yoldia eightsi* (Couth.).

Order FILIBRANCHIATA.

Sub-order ANOMIACEA.

Family *Anomiidæ.*

*Anomia ephippium*, Linn.

Sub-order ARCACEA.

Family *Arcadæ.*

*Arca* (*Bathyarca*) *strebeli*, sp. n.
*Lissarca notorcadensis*, sp. n.
,, *rubrofusca*, Smith.

Sub-order MYTILACEA.

Family *Mytilidæ.*

*Mytilus edulis*, Linn.
,, *magellanicus*, Chemnitz.
,, *ovalis*, Lamarck.

*Philobrya meridionalis* (Smith).
„ *quadrata* (Pfeffer).
„ *wandelensis*, E. Lamy.
*Modiolarca mesembrina*, sp. n.

Order PSEUDOLAMELLIBRANCHIATA.

Family *Pectenidæ*.

*Pecten colbecki*, Smith.
„ *multicolor*, sp. n.
„ ? *patagonicus*, King.
„ *pteriola*, sp. n.
*Amussium octodecim-liratum*, sp. n.

Family *Limidæ*.

*Lima* (*Mantellum*) *goughensis*, sp. n.
„ (*Limatula*) *pygmæa*, Philippi.

Order EULAMELLIBRANCHIATA.

Sub-order SUBMYTILACEA.

Family *Lucinidæ*.

*Cryptodon falklandicus*, Smith.
*Cyamium antarcticum*, Philippi.
„ *falklandicus*, Melv. and St.

Family *Erycinidæ*.

*Lasæa consanguinea* (Smith).
*Kellia cycladiformis*, Desh.
„ *lamyi*, nom. nov.
? *Scacchia plenilunium*, sp. n.

Sub-order TELLINACEA.

Family *Tellinidæ*.

*Tellina* (*Mæra*) *pusilla* (Philippi).

Sub-order VENERACEA.

Family *Veneridæ*.

*Chione philomela* (Smith).
*Tapes* (*Amygdala*) *exalbida* (Chem.).

Sub-order MYACEA.

Family *Glycimeridæ.*

*Saxicava arctica* (L.), var. *antarctica*, Phil.

Sub-order ANATINACEA.

Family *Lyonsiidæ.*

*Lyonsia cuneata* (Gray).

Family *Anatinidæ.*

*Anatina elliptica*, King and Brod.

Order SEPTIBRANCHIATA.

Family *Cuspidariidæ.*

*Cuspidaria brucei*, sp. n.

B. FROM ASCENSION ISLAND.

*Lotorium grandimaculatum* (Reeve).
*Nerita* (*Thelicostyla*) *ascensionis*, Gmel.

C. FROM SALDANHA BAY, SOUTH AFRICA.

*Chætopleura papilio* (Spengler).
*Ischnochiton tigrinus* (Krauss).
*Chiton nigrovirens*, Blainville.
*Acanthochites garnoti*, Blainville.
*Bullia annulata* (Lam.).
„ *lævigata*, Chem. (=*lævissima*, Gmel.).
*Mytilus edulis*, L., var. *meridionalis*, Krauss.
*Mytilicardia* (*Thecalia*) *concamerata*, Brug.
*Tapes pullastra* (Montagu).
*Oxystele impervia*, Minhe.
„ *tigrina*, Chem.
*Crepidula hepatica*, Desh.
*Gyrineum* (*Argobuccinum*) *argus* (Gmel.).
*Phos plicosus*, Dunker.
*Cominella limbosa* (Lam.).
*Patella compressa*, L., var. *miniata*, Born.
„ (*Scutellastra*) *granatina*, L.
„ „ *oculus*, Born.
*Helcion pectinatum* (Born.).
*Fissurella mutabilis*, Sowerby.
*Megatebennus scutellum* (Gmelin).

# CATALOGUE OF THE MARINE MOLLUSCA OBTAINED IN

A. Regio Antarctica, including Gough Island.
B. Ascension Island.
C. Saldanha Bay, South Africa.

## A.—Regio Antarctica.

### Class GASTEROPODA.

### Order Amphineura.

### Sub-order POLYPLACOPHORA.

*Callochiton illuminatus* (Reeve).

*Chiton illuminatus*, Reeve, *Conch. Icon.*, tab. xxii., fig. 147 (1847).
*C. (Callochiton) illuminatus*, Smith, *Proc. Zool. Soc. Lond.*, p. 35 (1881).
*Lepidopleurus illuminatus*, Rochebrune, *Mission, Cape Horn*, p. 141.
*Callochiton illuminatus*, Tryon and Pilsbry, *Man. Conch.*, vol. xiv., p. 51, pl. ix., figs. 92–94.

*Hab.*—Trawl, Burdwood Bank, 56 fathoms, December 1, 1903; also Port William, Falkland Islands, Station 118, January 1903.

A small, pale reddish or fawn-coloured species, the surface microscopically radiately striate and granulate, with the exception of the central areæ, which are longitudinally sulco-striate. The Port William examples are slightly larger and of a darker fawn colour.

*Tonicia atrata* (Sowb.).

*Chiton atratus*, Sowerby; Charlesworth's *Mag. Nat. Hist.*, 1840, p. 294; *Conch. Illustr.*, figs. 57, 58.
„ „ Reeve, *Conch. Icon.*, tab. xvii., fig. 103.
*Tonicia atrata* (Sowb.), H. and A. Adams, *Gen. Rec. Moll.*, i., p. 474.
„ „ „ Pilsbry, in Tryon's *Man. Moll.*, xiv., p. 201, pl. xli., figs. 28–30.

*Hab.*—Shore, Cape Pembroke, Falkland Islands; and also at Port Stanley, 1903–1904.

A smooth, sometimes prettily banded or rayed species. Several very juvenile examples from contiguous localities are of similar pattern, but we dare not attempt their differentiation.

### Order Prosobranchiata.

### Sub-order DIOTOCARDIA.

### Family *Acmæidæ*.

*Acmæa ceciliana*. Orbigny.

*Patella ceciliana*, Orb., *Voy. Amér. Mérid.*, p. 482, tab. lxxxi., figs. 4–6.
„ „ Gay, *Hist. Chili*, viii., p. 260 (1854).
*Acmæa ceciliana* (Orb.), Tryon, *Man. Conch.*, xiii., p. 33, pl. xxxiv., figs. 14–21.

*Hab.*—Trawl, Port William, Falkland Islands, January 31, 1903.

A small but attractive species. We have received it previously from the same locality. It was found, for instance, by Mr RUPERT VALLENTIN,* and likewise by Miss COBB, in Lively Island, in the enumeration of whose Mollusca † we at first named it *textilis*, Gould, a species confined to the western coasts of America.

Family *Patellidæ*.

*Patella ænea*, Martyn, var. *deaurata*, Gmel.

*Patella deaurata*, Gmelin, *Syst. Nat.*, xiii., p. 3703.
*Nacella ænea*, Mart., var. *deaurata*, Gmel.; Tryon, *Man. Conch.*, xiii., p. 118, pl. xlvi., figs. 28–36.
*Patella ænea*, Reeve, *Conch. Icon.* (*Patella*), fig. 9 (1855).

*Hab.*—Stanley Harbour, Falkland Islands, shore.

*Patella fuegiensis*, Reeve.

*Patella fuegiensis*, Reeve, *Conch. Icon.*, *Patella*, fig. 73 (1855).
„ (*Patinella*) *fuegiensis*, Smith, *Phil. Trans. Royal Soc. Lond.*, vol. clxviii., p. 180, tab. ix., figs. 14, 14*a*.
*Nacella fuegiensis*, Tryon, *Man. Conch.*, xiii., p. 121, pl. xlix., figs. 28–31 (1891).

*Hab.*—On shore rocks, Hearnden Water, Falkland Islands, January 7, 1903.

In somewhat puny condition, showing somewhat uneven ribs, and close latticed sculpture.

*Patella polaris*, Hombr. and Jacq.

*Patella polaris*, Hombron and Jacquinot, *Ann. des Sci. Nat.*, II., xvi., p. 191 (1841).
„ „ v. Martens and Pfeffer, "Mollusken von Süd-Georgien," *Jahrb. Hamburg. Wiss. Anstalt*, iii., p. 101, tab. 2, figs. 11–13 (1886).
*Nacella polaris* (H. & J.), Tryon, *Man. Conch.*, xiii., p. 120, pl. xlix., figs. 21–27 (1891).

*Hab.*—Dredged, Scotia Bay, South Orkneys, at 5–10 fathoms, January 2, 1904. Also at 1½ fathoms, December 3 and 18, 1903; and again at 6 fathoms, February 1, 1904.

Station 325, Scotia Bay, South Orkneys. Dredged at 9–15 fathoms, December 17, 1903, and various antecedent and subsequent dates.

Section **Zygobranchiata**.

Family *Fissurellidæ*.

*Fissurella oriens*, Sow.

*F. oriens*, Sow., *P.Z.S.*, 1834, p. 124; *Conch. Illust.*, fig. 25; *Thes. Conch.*, iii., p. 186, figs. 19, 20. Reeve, *Conch. Icon.*, fig. 13.

*Hab.*—Shore, Port William, Falkland Islands, January 31, 1904.

* *Journ. of Conch.*, vol. ix., p. 103 (1898). † *Ib.*, vol. x., p. 45 (1900).

### *Fissurella picta* (Gmel.).

*Un Lépas rare de Magellan*, etc., Davila, *Cat. Syst. et Raisonné des Cur., etc.*, i., p. 88, tab. iii., fig. 6, 1767.
*Lepas ovata ampla*, etc., Martini, *Syst. Conchyl. Cat.*, vol. i., p. 131, tab. xi., fig. 90.
*Patella picta*, Gmel., in *Syst. Nat.*, xiii., p. 3729.
*Fissurella picta*, Gould, *U.S. Expl. Exped.*, atlas, tab. 31, fig. 469, animal.

*Hab.*—Dredged in 6 fathoms, Port Stanley, Falkland Islands, February 2, 1904.

### *Tugalia antarctica*, sp. n. (Plate, fig. 1).

T. testa alba, oblonga, conico-depressa, parmophoroide, apice incurvo, posticé subimpendente, anticé obscuré intus sulcato, superficie extus pulcherrimé cancellata, striis tenuissimis, apud latera crassioribus, decorata, undique concentricé delicaté et arcté striata, et liris incrementalibus irregulariter prædita, intus alba, nitida, marginibus minuté crenulatis.

Alt. 7, long. 23, lat. 13 mm. spec. maj.
„ 4, „ 16, „ 10 „ „ min.

*Hab.*—Burdwood Bank, south of the Falkland Islands, at 56 fathoms.

Allied to *T. elegans*, Gray, *ossea*, Gould, and *parmophoroidea*, Quoy, but of much finer sculpture and more convex. The internal groove leading to the sinus is, indeed, present, but very obscurely indicated, its region, however, being noted by the absence of longitudinal sculpture dorsally.

## Section **Azygobranchiata**.

### Family *Trochidæ*.

### *Photinula expansa* (Sow.).

*Trochus expansus* (*Margarita*), Sowerby, *Conch. Illustr.*, figs. 16, 17. Philippi in *Mart. and Chem.*, ed. ii., p. 254, tab. xxxvii., fig. 18.
*Trochus* (*Photinula*) *expansus*, E. A. Smith, *Phil. Trans. Roy. Soc.*, vol. clxviii., p. 167 (1879).
*Photinula expansa* (Sow.), H. and A. Adams, *Gen. Rec. Moll.*, vol. i., pp. 427, 428 (1858).
„ „ v. Jhering, in *Nachrichtsbl. malak. Gesellsch.* (1902), p. 99.

*Hab.*—Station 118, trawl, Burdwood Bank, at 56 fathoms, December 1, 1903; also trawl, Port Stanley, Falkland Islands, at 1–10 fathoms, January 25, 1903.

### *Photinula tæniata* (Wood).

*Trochus tæniatus*, Wood, *Ind. Suppl.*, pl. v., fig. 12.
*Margarita tæniata*, Reeve, *Conch. Icon.*, pl. xx., figs. 4, 4*a*.
*Photinula tæniata*, H. and A. Adams, *Gen. Rec. Moll.*, i., p. 427 (1858). v. Jhering in *Nachrichtsbl. malak. Ges.* (1902), p. 101.

*Hab.*—Trawl, Port William, Falkland Islands, at 6 fathoms, January 1903.

*Photinula violacea* (King).

*Margarita violacea*, P. P. King, *Zool. Journ.*, No. xix., London (1832), p. 346.
„ „ Hombr. and Jacquin., p. 59, pl. xiv., figs. 29–31.
*Trochus violaceus*, Philippi, *Conch. Cab.*, ii., p. 254, pl. xxxvii., fig. 19.
*Photinula halmyris*, Rochebrune and Mabille, *Miss. Cap Horn*, Paris (1889): "Mollusques," p. 89, pl. iv., fig. 6.
*Photinula violacea*, v. Jhering, in *Nachrichtsbl. malak. Ges.* (1902), p. 98.

*Hab.*—Trawl, Burdwood Bank, at 56 fathoms.

A very nacreous, pink-tinged species, with spire more or less elevated.

*Valvatella antarctica* (E. Lamy).

*Margarita antarctica*, Ed. Lamy, *Expéd. Antarctique Française* (1907), p. 9, planche i., figs. 2, 3.
„ „ "Moll. Orcades du Sud," *Bull. Mus. Hist. Nat.*, t. xii., p. 123 (1906).

*Hab.*—Scotia Bay, South Orkneys, 9–10 fathoms, April 1903. Station 325, 9 fathoms, August 1903. Macdougal Bay, South Orkneys, at 10 fathoms, December 1903; also in shore pools in Scotia Bay.

A smooth, *Photinula*-like species, but easily distinguished by the deep umbilicus. We follow Mr Edgar Smith (*Nat. Antarct. Exped.: Nat. Hist.*, vol. ii., p. 11) in use of the generic name *Valvatella*, Gray (1857), and would refer to *Proc. Mal. Soc.*, vol. iii. (1898), p. 205, and *Journ. Conch.*, viii. (1897), p. 472, in justification thereof.

Sub-order MONOTOCARDIA.

(*a*) Ptenoglossa.

Family *Ianthinidæ*.

*Ianthina exigua*, Lamarck.

*Ianthina exigua*, Lam., *Anim. sans Vert.*, vi., p. 206.
„ „ Tryon, *Man. of Conch.*, p. 37, pl. x., figs. 17–22.

*Hab.*—Station 72, tow-net, lat. 34° 2′ S., long. 49° 7′ W.

Small but perfect and characteristic examples, pale, but finely striate.

(*b*) Tænioglossa.

Family *Naticidæ*.

*Natica* (*Lunatia*), sp.

*Hab.*—Surface-dredged by tow-net, lat. 9° 6′ S., long. 31° 45′ W.

A few very minute, evidently juvenile forms. They are white, shining, globose, four-whorled, including the small, dark-coloured apical, hardly perforate, mouth large proportionately, operculum corneous, paucispiral.

## Family *Capulidæ*.

### *Calyptræa costellata*, Phil.

*Calyptræa costellata*, Philippi, in *Arch. Naturg.* (1845), p. 62.
*Trochita corrugata*, Reeve, *Conch. Icon.*, xi., fig. 96 (1858).
„ „ Sowerby, *Thes. Conch.*, v., p. 89.
*Calyptræa costellata*, Phil.; H. Strebel, "Mollusken Fauna der Magalh. Prov.," *Zool. Jahrb. Jena* (1906), p. 159, Taf. xiii., figs. 88–97.

*Hab.*—Trawl, 56 fathoms, Burdwood Bank, lat. 50° 25′ S., long. 51° 0′ W.
All of the form *clypeolum*, Reeve, figured by STREBEL, Taf. xiii., figs. 93 *a*, *b*.

### *Crepidula dilatata*, Lam.

*Crepidula dilatata*, Lamarck, *Anim. sans Vert.*, vii., p. 644.
„ „ „ Sowerby, *Thes. Conch.*, v., p. 65, figs. 100, 101.
„ „ „ Reeve, *Conch. Icon.*, xi., 3.
„ „ „ Hermann Strebel, "Mollusken Fauna der Magalh. Prov.," *Zool. Jahrb. Jena* (1906), p. 166, Taf. xiii., figs. 100, 101.

*Hab.*—Trawl, Port William, Falkland Islands, 6 fathoms.

An abundant species. The synonymy is very extensive. We have given it all, briefly, in *Journ. Conch.*, ix., p. 101.

## Family *Littorinidæ*.

### *Littorina* (*Lævilitorina*) *caliginosa* (Gould).

*Littorina caliginosa*, Gould, *Proc. Boston Soc.*, iii., p. 83 (1849).
*Hydrobia caliginosa* (Gld.), E. Smith, *Phil. Tr. Roy. Soc. Lond.*, clxviii., p. 173, pl. ix., fig. 8 (1879).
*Lævilitorina caliginosa* (Gould), Pfeffer, in *Mollusken von Süd-Georgien*, p. 81, Taf. i., fig. 8, *a–d* (1886).
„ „ Pelseneer, *Voy. "Belgica": Zool., Moll.*, p. 8. E. Lamy, "Moll, Orcades du Sud," *Bull. Mus. Hist. Nat.*, t. xii. p. 112.

*Hab.*—Trawl, Port William, January 31, 1904; and also Hearnden Water, Falkland Islands, January 7, 1903.

### *Littorina* (*Lævilitorina*) *coriacea*, sp. n. (Plate, fig. 2).

L. (Lævilitorina) testa pertenui, coriacea, periostraco corneo brunneo-olivaceo contecta, ovato-oblonga, haud nitente, anfractibus 5–6, quorum apicalis parvus, obtusus, cæteris apud suturas impressis, tumidulis, apertura feré rotunda, peristomate tenui, flexili, margine columellari paullum producto.
Long. 7, lat. 3 mm.

*Hab.*—Scotia Bay, South Orkneys. Dredged at 5–10 fathoms, January 2, 1904.

More oblong than any form of *L. caliginosa*, Gould, and likewise larger than the

several Georgia Island species described by Dr PFEFFER.* It is of remarkably thin substance, covered with a leathery brownish-olive epidermis, which extends over the outer lip, and to some extent also round the columellar margin, which is slightly basally produced.

*Littorina* (*Pellilitorina*) *pellita*, v. Marts.

*Littorina pellita*, E. von Martens, "Moll. Süd-Georgien," *Sitz. Ges. Naturf. Fr. Berlin Jahrg.*, 1885, p. 92.
*Lævilitorina pellita* (Marts.), v. Martens and Pfeffer, "Moll. Süd-Georgien," *Jahrb. Hamburg. Wiss. Anst.*, iii. Jahrg., p. 79, pl. i., figs. *b*, *d* (1886).
*Littorina* (*Pellilitorina*) *pellita* (Marts.), E. A. Smith, "*Southern Cross*" *Antarct. Exped.*, p. 204 (1902).

*Hab.*—Shore pools, Scotia Bay, South Orkneys, December 6, 1903. Station 325. Off weed and stones at 9–10 fathoms, May 1903.

The largest example (alt. 15, lat. 12 mm.) comes from Scotia Bay.

*Littorina* (*Pellilitorina*) *setosa* (Smith).

*Littorina setosa*, E. A. Smith, *Ann. and Mag. N. Hist.*, xvi., p. 69 (1875); *Phil. Trans. Roy. Soc. Lond.*, vol. clxviii., p. 172, pl. ix., fig. 6.

*Hab.*—Station 325, Scotia Bay, South Orkneys, 9–10 fathoms, June 1903.

Much more uncommon than *L. pellita*, v. Marts. Our few examples are hardly typical, and in form show affinity with *pellita*. We are indebted to Mr E. A. SMITH for having examined them.

*Lacuna divaricata*, Fabr.

*Trochus divaricatus*, Fabr., *Faun. Grœnland.*, p. 392 (1780).
*Lacuna vincta*, Forbes and Hanley, iii., p. 62, pl. lxxii., figs. 10–12; lxxiv., figs. 7, 8; lxxxvi., figs. 6–8.

*Hab.*—Shore, Port William, Falkland Islands, January 31, 1904.

We cannot dissociate the Antarctic specimens from those of Arctic or British shores. One example is banded, being probably the var. *fasciata*, Brown.

*Lacuna notorcadensis*, sp. n. (Plate, figs. 3, 3*a*).

L. testa parum rimata, ovato-rotunda, tenui, cinereo-alba, undique epidermide tenui straminea induta, anfractibus 4–5, quorum apicalis minutus, obtusus, lævis, cæteris apud suturas gradatis, spiraliter acuté penultimo quadri-, ultimo anfractu octo-carinato, lineis incrementalibus obscuris longitudinaliter præditis, apertura feré rotunda, labro paullum effuso, continuo, columella feré recta.

Long. 3, lat. 3 mm.

*Hab.*—Station 325, Scotia Bay, South Orkneys, 9–10 fathoms, April 1903.

Much resembling in general appearance, though not in substance and texture, a *Fossarus*, this little shell might possibly find a place near *Lævilitorina umbilicata*,

* VON MARTENS and G. PFEFFER, *Mollusk. von Süd-Georgien*, pp. 81 *sqq.*

Pfeffer, which possesses slightly impressed carinæ on the body-whorl; or, with greater probability, in proximity to certain *Lacunæ*, being nearly allied to *L. wandelensis*,* Lamy, an Antarctic species recently described from Carthage Bay, Wandel Island. The substance is thin, covered with a pale and fugitive epidermis. The spiral keels on the body-whorl are eight in number, as against only five in *L. wandelensis*; of these one is obscure, the others seem strong and well defined; the spire likewise is more elevated.

## Family *Rissoidæ*.

### *Rissoa adarensis*, Smith.

*Rissoa adarensis*, E. A. Smith, *Rep. "Southern Cross" Exped. Antarctic*, Brit. Mus. (1902), p. 205, pl. xxiv., fig. 17.
„ „ *Nat. Ant. Exp.*, vol. ii., p. 8 (1907), pl. ii., fig. 2.

*Hab.*—Station 325, Scotia Bay, South Orkneys, 9–15 fathoms.

A few examples, almost typical. The author of the species considers the whorls rather less convex than in the type.

### *Rissoa* (*Cingula*) *cingillus* (Mont.).

*Turbo cingillus*, Montagu, *Test. Brit.*, p. 328, pl. xii., fig. 7.
*Rissoa cingillus*, Forbes and Hanley, vol. iii., p. 122, pl. lxxix., figs. 9, 10.
„ „ Jeffreys, *Brit. Conch.*, iv., p. 48.

*Hab.*—Station 325, Scotia Bay, South Orkneys. Dredged at 9–15 fathoms, April 1903.

We cannot separate the single example received from the European species, so similar is it in both form, size, and coloration. It may be that further supplies will show it to be a nearly allied southern species, though we are dubious as to this point.

### *Rissoa edgariana*, sp. n. (Plate, fig. 4).

R. testa oblongo-fusiformi, vix rimata, parva, solidula, lævigata, anfractibus ad 7, quorum apicales duo minuti, tumiduli, brunnei, cæteris apud suturas paullum impressis, subventricosis, pallide stramineis, flammis longitudinalibus fulvo-brunneis indistinctis ornatis, ultimo magnitudine cæteros exæquante, infra peripheriam versus basim spiraliter zonula fulvo-brunnea succincta, apertura ovata, peristomate tenui feré continuo, paullum expanso, columella paullum incrassata.

Alt. 3·5, lat. 1·25 mm.

*Hab.*—Scotia Bay, South Orkneys, 9–15 fathoms.

A brightly coloured, smooth, subhyaline species when in fresh condition. The majority, however, of those collected being defunct, are more solid in appearance. The markings are indistinct longitudinal brown flames surrounding the whorls; and on the

* *Expéd. Antarct. Franç. Charcot*, "Mollusques," par E. Lamy (1907), *Bull. Mus. Hist. Nat. Paris* (1905), p. 478, figs.

body-whorl itself, below the periphery, there is a pale fulvous-brown spiral zone. We are indebted to Mr EDGAR SMITH for having examined this and other species, and have much pleasure in connecting his name with it.

*Rissoa fraudulenta*, Smith.

*Rissoa fraudulenta*, E. A. Smith, *Nat. Ant. Exped., Nat. Hist.*, ii., p. 9, pl. ii., fig. 3 (1907).

*Hab.*—Scotia Bay, South Orkneys. Dredged, 6 fathoms.

Fine examples of this newly described, spirally striate *Rissoa*, differing from the types in being straw-coloured, otherwise identical.

*Rissoa parva* (Da Costa).

*Turbo parvus*, Da Costa, *Brit. Conch.*, p. 104.
*Rissoa parva*, Forbes and Hanley, iii., p. 98, pl. lxxvi., figs. 2, 6; pl. lxxvii., figs. 6, 7; and pl. lxxxii., figs. 1–4.
" " Jeffreys, *Brit. Conch.*, iv., p. 23; v., pl. lxvii., fig. 3.

*Hab.*—Shore, Port William, Falkland Islands, January 31, 1904.

These specimens cannot be dissociated from the typical European and British shell, and have probably been accidentally imported into the Falkland Islands.

*Rissoa* (*Onoba*) *Scotiana*, sp. n. (Plate, fig. 5).

R. (Onoba) testa albida, imperforata, solidiuscula, fusiformi, anfractibus 6, quorum apicales duo pervitrei, globulares, cæteris apud suturas impressis, ventricosis, undique arctissimé spiraliter striatis, ultimo anfractu zonula straminea obscura ad medium prædito, superficie interdum obscuré longitudinaliter costellata, apertura semicirculari, intus albo-lactea, peristomate incrassato, continuo, paullum effuso, columella obliqua.

Long. 3, lat. 1 mm.

*Hab.*—Station 325, Scotia Bay, South Orkneys, 9–15 fathoms, April 1903.

With a superficial resemblance to *Rissoa* (*Onoba*) *striata*, Mont., a well-known European species, this little shell seems, likewise, akin to *R.* (*Ceratia*) *turqueti*, E. Lamy,* recently described from Wandel Island, from which it differs in possessing one whorl more, in being not in the least degree rimate, in the thickened continuous peristome, and the obscure spiral straw-coloured zone encircling the body-whorl. Perhaps, in time to come, additional links to bind these two species together may be found.

*Rissoa* (*Manzonia*) *zetlandica* (Mont.).

*Turbo zetlandicus*, Montagu, *Trans. Linn. Soc.*, xi., p. 194, t. xiii., fig. 3.
*Rissoa zetlandica*, Forbes and Hanley, iii., p. 78, pl. lxxx., figs. 1, 2.
" " Jeffreys, *Brit. Conch.*, iv., p. 20; v., pl. lxvii., fig. 1.

*Hab.*—Shore, Port William, Falkland Islands, January 31, 1904.

Obtained at the same time as *R. parva* (Da Costa), it is equally probable that this,

* *Bull. Mus. Hist. Nat. Paris* (1905), p. 479, fig.; *Expéd. Charcot*, p. 6, pl. i., fig. 8.

of which only one somewhat broken example occurred, is not a genuine native of these southern shores and seas.

*Eatoniella kerguelenensis*, Smith.

*Eatonia kerguelenensis*, E. A. Smith, *Ann. and Mag. N. Hist.*, xvi. (1875), p. 70.
*Eatoniella kerguelenensis* (Sm.), Dall., *Bull. N.S. Nat. Mus.*, iii., p. 42 (1876).
" " E. Smith, "Zool. Kerguelen Moll.," *Phil. Trans. Roy. Soc. Lond.*, clxviii., p. 174, pl. ix., fig. 40 (1879).
*Rissonia* (*Eatoniella*) *kerguelenensis*, Smith, *Man. Conch.*, ix., p. 391, pl. lx., fig. 67 (1887).

*Hab.*—Scotia Bay, South Orkneys, 9–10 fathoms, April 1903. Station 325, contiguous to first locality, 9–10 fathoms, July 1903; also shore pools in Scotia Bay, December 6, 1903.

Quite typical, often encrusted with nullipore. Found likewise in South Georgia.* A further extension of range is now established.

Family *Litiopidæ*.

*Litiopa melanostoma*, Rang.

*Buccinum litiopa*, M. E. Gray, *Figs. Moll. Anim.*, i., t. 24, figs. 1, 2.
*Litiopa melanostoma*, Rang., *Ann. des Sci. Nat.*, xvi., p. 303 (1829); *Man. Hist. Moll.*, p. 129.
" *bombix*, Rang., *l.c.*, p. 303 (1829).
" *maculata*, d'Orb., *Moll. Cuba*, ii., p. 149.

*Hab.*—With tow-net, surface-dredging, and upon gulf-weed (sargassum); in several places, including particularly lat. 9° 6′ S., long. 31° 45′ W., December 16, 1902; and lat. 29° 54′ N., long. 34° 10′ W., June 29, 1904.

Very variable, and with a lengthened synonymy, of which only two or three have been given above.

Family *Cerithidæ*.

*Cerithium georgianum*, Pfeffer.

*Cerithium georgianum*, Pfeffer; von Martens and Pfeffer, *Mollusken von Süd-Georgien*, p. 97, Taf. ii., fig. 7 (1886).

*Hab.*—Scotia Bay, South Orkneys, 9–10 fathoms, April 1903.

One example only, but in fine condition, entirely agreeing with Dr PFEFFER's plate and description of his South-Georgian species. It is a curious, small, strongly spirally ribbed and keeled shell, the carinæ three in number on the lower whorls, four on the body-whorl itself. The apex is remarkably obtuse.

* PFEFFER and VON MARTENS, *Die Mollusken v. Süd-Georgien*, 1886, p. 94, Taf. ii., fig. 5 *a*, *b*.

### *Cerithium pullum*, Phil.

*Cerithium pullum*, Philippi, in *Arch. Naturg.*, 1845, p. 66.
„ *cælatum*, Couthouy; Wilkes, *Expl. Exped.*, p. 148, fig. 174 *a–d*. Gould, *Bost. Proc.*, iii., p. 123 (1849).
*Bittium cælatum*, Couthouy, *Mission de Cap Horn*, p. 40.
*Cerithium pullum* (Phil.), H. Strebel, "Beitr. der Mollusk. Fauna der Magalhaen Provinz," *Zool. Jahrb. Jena*, 1905, p. 652, Taf. xxiii., fig. 40 *a–d*.

*Hab.*—Cape Pembroke, Falkland Islands, shore.

Only dead and broken examples, but retaining the peculiar sculpture of this well-known species.

### *Cerithiopsis malvinarum* (Strebel, MS.), sp. n. (Plate, figs. 6, 6*a*).

C. testa parva, imperforata, eleganter fusiformi, brunneo-castanea, anfractibus 7–8, apud suturas multum impressis, spiraliter fortiter bi-, ultimo tricarinulato, undique cancellatis et alveatis, apertura squarrosula, peristomate tenui, albescente, columella recta, paullum producta.

Long. 4, lat. 1·5 mm.

*Hab.*—Shore, Hearnden Water, Falkland Islands.

Dr Hermann Strebel kindly examined our only example, and returned it with the above MS. name, requesting us to describe it. He informs us another example was found at Port Louis, by the Swedish South Polar Expedition, eight-whorled, not quite adult, in measurement 3·9 × 1·4 × (aperture) 0·9 mm.; differentiated, but not yet published.

## Family *Tritonidæ*.

### *Gyrineum vexillum* (Sowerby).

*Ranella vexillum*, Sowerby, jr., *Conch. Illust.*, fig. 3.
„ „ Deshayes, in *Lam. sans Vert.*, ix., p. 553, No. 30.
„ „ Reeve, *Conch. Icon.*, iii., t. 3, fig. 13.
*Triton ranelliformis*, King, *Zool. Journ.*, v., p. 347.

*Hab.*—Gough Island, trawl, 100 fathoms.

Only in juvenile condition. By some authors the *Ranella vexillum*, Sowb., is considered but a variety of the *R. argus*, Gmelin.

## (*c*) Gymnoglossa.

No representatives of this section occurred.

## (*d*) Rachiglossa.

## Family *Muricidæ*.

### *Trophon brucei*, Strebel.

*Trophon brucei*, H. Strebel, "Beitr. der Mollusk. Fauna der Magalh. Provinz," *Zool. Jahrb. Jena*, 1904, p. 230, Taf. viii., fig. 72.

*Hab.*—Station 118, Port Stanley, Falkland Islands, trawl, at 1–10 fathoms, January 25, 1903.

Near *T. liratus*, Couth., but of peculiar form. A larger series of specimens than we have seen is required to decide whether this be constant.

### *Trophon cinguliferus*, Pfeffer.

*Trophon cinguliferus*, G. Pfeffer ; E. von Martens and G. Pfeffer, *Mollusken von Süd-Georgien*, Hamburg (1886), p. 70, Taf. i., fig. 2 *a*, *b*.

*Hab.*—Dredged, 2–3 fathoms, Scotia Bay, South Orkneys, December 3, 1903. Also trap, Brown's Bay, South Orkneys, November 1903.

Thus showing extension of geographical range. This species has a wonderful resemblance to certain forms of *Purpura lapillus* (L.).

### *Trophon crispus* (Couth.).

*Fusus crispus*, Couthouy ; Gould, in *Wilkes' Expl. Exped.*, p. 229, fig. 279 *a–c*.
,, *fimbriatus*, Hupé ; Gay, *Hist. de Chili*, p. 165, pl. iv., fig. 7.
,, ,, Smith, "*Alert* Surv.," *P. Z. Soc. Lond.*, 1881, tab. iv., fig. 4.
,, *crispus*, Herm. Strebel, "Beitr. der Mollusk. der Magalhaen Prov.," *Zool. Jahrb. Jena*, 1904, p. 204, Taf. iii., fig 10 *a–g*.

*Hab.*—Burdwood Bank, lat. 50° 25′ S., long. 51° 0′ W., 56 fathoms, trawl, December 1, 1903. Port William, Falkland Islands, trap, 6 fathoms, January 1903.

### *Trophon geversianus* (Pallas).

*Buccinum geversianum*, Pallas ; Spicil., *Zool.*, fasc. 10, p. 33, pl. iii., fig. 1. Chemnitz, *Conch. Cab.*, vol. iv., p. 130, pl. cxxxix., fig. 1297.
*Murex magellanicus*, Gmelin, p. 3548, No. 80 (*excl.* var. *β*).
,, *magellanicus* and *Murex peruvianus*, *Encyclop. Méthod.*, vers., pl. ccccxix., figs. 4, 5.
,, *lamellosus*, Dillwyn, vol. ii., fig. 730, No. 97.
,, *magellicanus*, Wood, *Ind. Test.*, p. 132, pl. xxvi., fig. 90.
,, ,, Lamarck, *Anim. s. Vert.*, vol. vii., p. 171, and (ed. Desh.) vol. ix., p. 589, sp. 46 (note).
,, ,, D'Orbigny, *Amérique méridionale*, vol. v., p. 451, No. 392.
,, *patagonicus*, D'Orbigny, *Amérique méridionale*, vol. v., p. 254, pl. lxii., figs. 2, 3, No. 393.
,, *varians*, D'Orbigny, *Amérique méridionale*, vol. v., p. 452, pl. lxii., figs. 4–7, No. 394.
*Fusus geversianus*, Reeve, *Conch. Icon.*, vol. iv., pl. iv., fig. 2.
*Trophon geversianus*, Sowerby, *Thes. Conch.*, pt 35, p. 59, sp. 1, pl. cccciv. (i. *Gen.*), figs. 7, 8.
,, ,, Kobelt, in *Conch. Cab.* (ed. Kuster), pp, 275, 305, sp. 1, pl. lxxii., figs. 1–3, and pl. lxxiii., fig. 1, pl. lxxv., fig. 1, pl. lxxvi., figs. 1–2.
,, ,, Tryon, vol. ii., p. 144, pl. xxxii., figs. 337–347, and pl. lxx., figs. 433, 435.

*Hab.*—Port William, Falkland Islands, trawl, January 31, 1903. Scotia Bay, South Orkneys, trawl, 9–10 fathoms, December 17, 1903.

### *Trophon hoylei*, Streb.

*Trophon hoylei*, H. Strebel, "Beitr. der Mollusk. Fauna der Magalh. Provinz," *Zool. Jahrb. Jena*, 1904, p. 227, Taf. viii., figs. 68 *a–f*, 69 *a–c*.

*Hab.*—Shore, Port William, Falkland Islands, January 31, 1904.

We are not satisfied as to the specific distinctness of this species from *T. liratus*, Couth. The form and texture seem almost identical, but coloration, notably the dark purpurescent aperture, somewhat different.

### *Trophon liratus* (Couth.).

*Fusus liratus*, Couthouy ; Gould, *Wilkes' Expl. Exped.*, p. 231, fig. 282 *a–c*.

*Hab.*—Station 118, Stanley Harbour, Falkland Islands. Dredged at $3\frac{1}{4}$ fathoms, January 15, 1903.

Many fine examples, in perfect condition, with operculum. We consider this the *Buccinum cancellarioides*, Reeve. It is evidently variable, and out of the forms Dr Hermann Strebel (to whom we are much indebted for the examination of our examples of this and its allies) has recently propounded several new species.

### *Trophon minutus* (Strebel, MS.), sp. n. (Plate, figs. 7, 7*a*).

T. testa parva, fusiformi, albo-cinerea, anfractibus 5–6, quorum apicales 2 hyalini, perlæves, cæteris apud suturas multum impressis, gradatulis, longitudinaliter arctissimé costatis, costis lævibus, incrassatis, numero ultimum apud anfractum circa 22, interstitiis lævibus, apertura ovata, albo-lactea, labro paullum effuso, superné rectangulo, columella recta, canali paullum prolongato, lato.

Long. 7·3, lat. 4, apertura 4 mm.

*Hab.*—Station 325, Scotia Bay, South Orkneys, 9–15 fathoms, April–August 1903, February 1, 1904.

We are requested by Dr Hermann Strebel to draw up the description as above of a small *Trophon*, already differentiated by him in MS. as having been found in South Georgia Island recently by the Swedish South Polar Expedition. Only one example was dredged, not so perfect as our specimens, nor so large, having the apical whorls broken off, and but $3\frac{1}{2}$ conserved whorls, measuring 3·7 × 1·9 mm., and numbering only 17 costæ on body-whorl, as against 22 in our type. On this account he suggests the varietal term *major* being applied to the South Orkney specimens, of which only two or three examples occurred, dredged from time to time in Scotia Bay.

### *Trophon philippianus*, Dunker.

*Trophon philippianus*, Dkr. ; Mart. and Chem., ed. ii. (W. Kobelt), fol. 279, tab. lxxii., figs. 4, 5.

,, *geversianus* (*fusus*), Gould, in *Wilkes' Explor. Exped.*, p. 228. Var. *philippianus*, Dkr. ; H. Strebel, *Zoologisch. Jahrb.*, p. 174 (1904).

*Hab.*—Shore, and at 6 fathoms, Port Stanley, Falkland Islands.

This agrees with specimens from Punta Arenas we have compared it with in the British Museum, and we are confirmed in our determination by Dr STREBEL.

Family *Nassidæ*.

*Nassa* (*Ilyanassa*) *vallentini*, sp. n. (Plate, figs. 8, 8*a*).

N. testa ovato-oblonga, solidula, plicato-corrugata, plumbeo-brunnescente, anfractibus 7, quorum 2 apicales plus minus læves, cæteris irregulariter longitudinaliter crassicostatis, apud suturas magis incrassatis, impressis, arctissimé spiraliter liratis, liris rudibus, apertura rotundo-ovata, intus plumbeo-fusca vel brunnescente, labro tenui, columella paullum excavata, haud callosa, canali ad basim breviter recurva.

Long. 14, lat. 8 mm.

*Hab.*—On the shore, Port William, Falkland Islands.

To some extent resembling *N.* (*Ilyanassa*) *obsoleta*, Say.—a common estuarine species on the Atlantic shores of the United States,—this Antarctic representative differs entirely in characters of sculpture, being conspicuous for its irregular thickened plicate costæ, the whole surface being spirally sulco-lirate, mouth oval, leaden-coloured or red-brown, outer lip hardly thickened, columella slightly excavate, with no callus, canal basally shortly recurved.

We name this Falkland Islands species after one who has in late years most thoroughly explored that group, our friend Mr RUPERT VALLENTIN.

Family *Buccinidæ*.

*Chrysodomus* (*Sipho*) *archibenthalis*, sp. n. (Plate, fig. 9).

C. (Sipho) testa fusiformi, tenui, albo-cinerea, undique epidermide pallidé straminea tenuissima prædita, anfractibus, in specimine unico imperfecto, ad sex, quorum apicales duo læves, submamillati, cæteris apud suturas impressis, tumidulis, spiraliter arcté liratis, liris anfractûs ultimi circá 12 suprá peripheriam, apertura ovata, columella paullum excavata, columella brevi. Operculo lutescente, unguiformi, corneo, nucleo apicali.

Long. 17, lat. 8 mm.

*Hab.*—Lat. 62° 10′ S., long. 41° 20′ W., 1775 fathoms, trawl, March 10, 1903.

Evidently not adult, and though this be the case, and the outer lip be to some extent broken away, we think this *Sipho* is worth describing, the upper whorls being very perfect. The ventricose, closely spirally lirate whorls seem characteristic. Only one specimen occurred, from the abysmal depth recorded above. It may be many years before another specimen is brought to light. We should imagine a full-grown shell would be at least twice the size—say 35 mm. in length.

*Chrysodomus* (*Sipho*) *crassicostatus*, sp. n. (Plate, figs. 10, 10*a*).

C. (Sipho) testa parva, ovato-fusiformi, solidula, albo-cinerea, periostraco tenui olivaceo-stramineo contecta, anfractibus 5–6, quorum apicales 2–3 gradati, subhyalini, læves, subtumidi, cæteris spiraliter crassicostatis, apud suturas impressis, ventricosis, ultimum apud anfractum numero 7, interstitiis lævibus, apertura ovata, labro paullum effuso, columella excavata, ad basim breviter truncatula.

Long. 6, at. 3 mm.

*Hab.*—Station 325, Scotia Bay, South Orkneys, 9–10 fathoms, off weed and stones, April–August 1903.

A very compact little species, of which a few examples, all precisely similar in size and sculpture, occurred. It is likely they are nearly, if not quite, adult, and are conspicuous for the strong, acute spiral liræ or riblets encircling the three lower whorls in a uniform fashion, there being seven on the body-whorl.

### *Neobuccinum eatoni* (Sm.).

*Buccinopsis eatoni*, Smith, *Ann. and Mag. N. Hist.*, xvi., p. 68 (1875).
*Neobuccinum eatoni*, Smith, *Phil. Trans. Royal Soc.*, clxviii. (1879), p. 169, pl. ix., figs. 1, 1*a*.
,, ,, ,, Tryon, *Man. Conch.*, iii., p. 197, pl. lxxvii., figs. 357, 358.
,, ,, ,, Watson, *Rep. "Challenger": Gastropoda*, p. 216 (1886).
,, ,, ,, E. A. Smith, "*Southern Cross*" *Mollusca*, p. 202 (1902).
,, ,, ,, E. Lamy, *Expéd. Antarctique Française* (1906), p. 2.

*Hab.*—Trawl, Scotia Bay, South Orkneys, 9–10 fathoms, December 17, 1903, and February 20, 1904.

Several examples, mostly in live condition. The shell is of such thin texture, and the animal, perhaps, so large and swollen proportionately, that most examples were found to have their penultimate whorls broken, and the flesh protruding, when dredged up.

### *Euthria fuscata* (Brug.).

*Buccinum fuscatum*, Bruguière, *Encycl. Méth.*, vers., p. 282 (1792).
,, *antarcticum*, Reeve, *Conch. Icon.*, iii., fig. 30 (1846).
*Tritonium schwartzianum*, Crosse, *Journ. de Conch.*, p. 174, tab. 6, figs. 9, 10 (1861).
*Euthria antarctica* (Reeve), H. and A. Adams, *Gen. Rec. Moll.*, t. i., p. 86 (1858).
,, ,, E. Lamy, "Gastr., Exp. Charcot," *Bull. Mus. Hist. Nat.*, t. xi., p. 476 (1905).
,, *fuscata* (Brug.), Hermann Strebel, "Mollusk. d. Magalhaen Provinz," *Zool. Jahrb.*, xxii., p. 611, pl. xxiv., figs. 69–72, 74–79 (1905).
,, ,, E. Lamy, *Expéd. Antarct. Française: Gastr. et Pelecyp.*, p. 2 (1907).

*Hab.*—Cape Pembroke, Falkland Islands, trawl, 1–10 fathoms, January 1903; also Port William, Falklands.

### *Euthria magellanica* (Philippi).

*Buccinum magellanicum*, Phil., *Abbildungen*, vol. iii., p. 48, tab. i., fig. 14 (1848).
*Fusus rufus*, Homb. and Jacq., *Voyage de l' "Astrolabe,"* vol. v., p. 107, tab. xxv., fig. 3 (1854).
*Euthria magellanica*, Phil.; H. Strebel, "Beitr. zur Kenntn. der Moll. Fauna der Magalhaen Prov.," *Zool. Jahrb.* (1905), p. 601.

*Hab.*—Port William, Falkland Islands.

### *Euthria michaelseni*, Streb.

*Euthria michaelseni*, H. Strebel, "Mollusken der Magalhaen Provinz," *Zool. Jahrb. Jena*, 1905, p. 621, pl. xxi., figs. 6, 6*a*, 6*b*.

*Hab.*—Port William, Falkland Islands, trawl, 6 fathoms, January 1903.

An interesting new form; conspicuous for a light spiral zone running round the centre of the body-whorl.

Family *Volutidæ*.

*Voluta* (*Cymbiola*) *ancilla* (Sol.).

*Voluta ancilla*, Solander, *Portland Cat.*, p. 137, No. 1873.
„ *gracilis*, Wood, *Ind. Test.*, p. 209, Suppl., pl. iii., fig. 2.
„ *ancilla*, Lamarck, *Anim. s. Vert.*, vol. vii., p. 343, and (ed. Desh.) vol. x., p. 397, sp. 33.
„ „ Deshayes, *Encycl. Méthod.*, vers., vol. iii., p. 1141, sp. 16, pl. ccclxxxv., fig. 3.
„ „ Kiener, *Conch. Cat.* (ed. Kuster), pp. 152, 153, pl. xxxii., fig. 4.
„ „ D'Orbigny, *Amér. Mérid.*, vol. v., p. 425, No. 333.
„ *magellanica*, Sowerby, *Thes. Conch.*, vol. i., pt. 5, pl. liv., fig. 99.
„ *ancilla*, Reeve, *Conch. Icon.*, vol. vi., pl. xvii., fig. 39.
„ *magellanica*, Gould, *U.S. Expl. Exped.*, p. 278, pl. xx., fig. 357.
„ *ancilla*, Crosse, "Cat. Voluta," *Jour. de Conch.*, 1871, vol. xix., p. 299, sp. 61.
„ (*Cymbiola*) *ancilla*, Kobelt, "Catalog Voluta," *Jahrb. deutsch. malak. Gesellsch.*, 1877, p. 310, sp. 61.
„ „ „ Tryon, *Manual*, vol. iv., p. 97, pl. xxix., fig. 110.

*Hab.*—Port William, Falkland Islands, trawl, 6 fathoms.

*Guivillea alabastrina*, Wats.

*Wyvillea alabastrina*, Watson, *Prelim. Report*, "*Challenger*" *Exped.*, p. 12; *Journ. Linn. Soc. Lond.*, vol. xvi., p. 332.
*Guivillea alabastrina*, Watson, *Rep.* "*Challenger*" *Exped.*: *Zool.*, "Gastropoda," vol. xv., pp. 262, 701, pl. xv., fig. 2.
*Voluta* (*Guivillea*) *alabastrina*, Wats.; Sowerby, *Thes. Conch.*, iii., p. 304, pl. xviii., fig. 169.

*Hab.*—Lat. 60° 10′ S., long. 41° 20′ W. Dredged at 1775 fathoms, March 18, 1903.

One example in live condition, but hardly adult, and which is in shattered condition, with the larger portion of the body-whorl missing, the body protruding. The comparison, however, of the portion remaining with the figure in "*Challenger*" *Report* seems to indicate similarity as regards size. The whole substance of the shell is of papyraceous fragility.

Section **Toxoglossa**.

Family *Conidæ*.

*Columbarium benthocallis*,* sp. n. (Plate, fig. 11*a*).

C. testa eleganter fusiformi, tenui, papyracea, alba, epidermide pallidé cinerea contecta, parum nitida, anfractibus ad 6–7, apicalibus . . . .? his ductus proximis erosis, quatuor ultimis fortissimé et ampliter apud medium carinatis, superficie undique tenuiter liratula, et longitudinaliter irregularibus striis incrementalibus prædita, ultimo anfractu subtus carina inferiori minus conspicua decorato, apertura subtriangulari, intus albo-cinerascente, peristomate tenui, margine columellari recto, canali longo, recto.

Long. 45, lat. (carina anfr. ultimi inclusa) 18 mm.

* βένθος κάλος, "beauty of the deep."

*Hab.*—Trawl, lat. 62° 10′ S., long. 41° 20′ W., 1775 fathoms, March 10, 1903.

A shell of papyraceous texture, as are so many abyssal species, whitish, with very thin ash-coloured epidermis. The apex of our only specimen is wanting, and the next two whorls much eroded; the remainder are embellished with a central very acute and bold keel; in the last whorl this carina is situate above the centre, and not far below the suture. A little lower comes a less-developed spiral keel. The triangular mouth is ashy-white within, the columellar margin straight, and the canal prolonged.

*Mangilia costata* (Donovan).

*Murex costatus*, Donovan, *Brit. Shells*, vol. iii., pl. xci.
*Pleurotoma costata*, Don.; Jeffreys, *Brit. Conch.*, vol. iv., p. 379.
*Mangelia costata*, Forbes and Hanley, iii., p. 485, pl. cxiv., A, figs. 3–5.

*Hab.*—Shore, Port William, Falkland Islands, January 31, 1904.

One somewhat shattered example, but agreeing with authentic Mediterranean and British examples of the northern *Mangilia costata* (Don.), which is reported from South Africa.

Family *Cancellariidæ*.

*Admete magellanica*, Strebel.

*Admete magellanica*, H. Strebel, *Zool. Jahrb.*, p. 594, Taf. xxii., figs. 29, 29 *a–d** (1905).

*Hab.*—Port Stanley, Falkland Islands, shore, January 31, 1904.
Allied to *A. delicatula*, Smith,* but with finer ribs.

Order OPISTHOBRANCHIATA.

Sub-order TECTIBRANCHIATA.

Family *Tornatinidæ*.

*Retusa truncatula* (Bruguière).

*Bulla truncatula*, Brug., *Encycl. Méth.*, p. 377 (1792).
*Utriculus truncatulus*, Jeff., *Brit. Conch.*, iv., p. 421, pl. xciv., fig. 2. Sars. *Moll. Reg. Arch. Norv.*, p. 285, pl. xxvi., fig. 2; pl. xvii., fig. 18.
*Retusa truncata*, Buq., Dantz., and Dollf., *Moll. Rouss.*, i., p. 527, pl. lxiv., figs. 12–14.
*Bulla truncata*, Ad. (non Gmelin), *Tr. Linn. Soc.*, v., p. 1, pl. i., figs. 1, 2.
*Volvaria truncata*, Brown, *Ill. Conch.*, G. B. ed., 1, pl. xix., figs. 17, 18.
*Cylichna truncata*, Loven, *Ind. Moll. Skand.*, p. 42. Forbes and Hanley, *Hist. Brit. Moll.*, iii., p. 510, pl. cxiv., figs. 7, 8; pl. vv. fig. 4 (animal). Meyer and Mobius, *Fauna der Kieler Bucht*, i., p. 87 (animal).
*Bulla retusa*, Maton and Rack., "Descr. Cat.," in *Trans. Linn. Soc.*, viii., p. 128 (1804).
*Retusa obtusa*, Brown, *Pop. Encycl.*, ii., p. 78, pl. xvii., fig. 110.
*Volvaria pellucida*, Brown, *Ill. Conch.*, G. B. edit., i., p. 4, pl. xix., figs. 45, 46.
*Utriculus truncatulus*, var. *pyriformis*, Monts., *Nom. Gen. e Spec.*, p. 50.

* *Nat. Antarct. Exped., Nat. Hist.*, vol. ii. (Brit. Mus. N.H.), 1907, p. 4, pl. i., figs. 5, 5*a*.

*Hab.*—Shore, Port William, Falkland Islands, January 31, 1904.
Indistinguishable from the European species.

Section **Siphonarioidea.**

Family *Siphonariidæ.*

*Siphonaria redimiculum*, Reeve.

*Siphonaria redimiculum*, Reeve, *Conch. Icon.*, ix., pl. v., fig. 21 (1856).
„ „ „ E. A. Smith, "Moll. of Kerguelen," in *Trans. Royal Soc. Lond.*, 1879, p. 16.

*Hab.*—Hearnden Water, Falkland Islands, shore, January 7, 1903; also trawl, Port William, Falkland Islands, January 31, 1903; Gough Island, on the shore, April 22, 1904.

Order PULMONATA.

Sub-order BASOMMATOPHORA.

Family *Auriculidæ.*

*Marinula nigra*, Philippi.

*Hab.*—Gough Island, on the shore, April 22, 1904.

Class SCAPHOPODA.

*Dentalium eupatrides*,* sp. n. (Plate, fig. 12).

D. testa magna, nitidissima, tenui, alba, paullum arcuata, polita, lineis incrementalibus concentrice prædita, versus apicem solum longitudinaliter obscuré multi-striata. Apice minimo, apertura rotunda.
Long. 63, diametr. antic. 5, diametr. post. 1 mm.

A fine, glistening white species, of thin and fragile substance. The concentric incremental lines of growth are frequent, and occasionally shown more plainly by staining of straw-colour. Towards the apex the surface is longitudinally closely striate, these striæ extending for almost one-third of the total length. Some examples are straighter than others; the majority are slightly gracefully arched. The aperture is circular, varying in diameter from 5 millimetres in the type, to 7 in one very broad specimen. From the figure and description† by Dr W. H. DALL, his *D. callipeplum* seems akin to our species. This was obtained in several stations in the West Indies during the *Blake* Expedition, at between 100 and 200 fathoms.

* εὐπατρίδης, patrician.
† *Bull. Mus. Comp. Zool. Harvard*, vol. xviii., p. 419, pl. xxvii., fig. 12*b* (1889).

*Dentalium shoplandi*, Jouss.

*Dentalium shoplandi*, Jousseaume, *Bull Soc. Philomath. de Paris*, vi., p. 102 (1894).

*Hab.*—Lat. 71° 22′ S., long. 16° 34′ S., 1410 fathoms.

Specimens are in the British Museum from "near Aden," dredged at 670 fathoms. We can see no difference in this southern form, either in size, texture, or sculpture. One example, dead, but characteristic.

## Class PELECYPODA.

### Order PROTOBRANCHIATA.

### Family *Nuculidæ*.

*Nucula minuscula*, Pfeffer.

*Nucula minuscula*, G. Pfeffer, in von Martens und Pfeffer's *Mollusken von Süd-Georgien*, p. 128, Taf. iv., fig. 15 (1886).

*Hab.*—Station 325, Scotia Bay, South Orkneys, 9–15 fathoms, April 1903.

A single example only, for the determination of which we are indebted to the author, Dr GEORG PFEFFER, of Hamburg. Its appearance in the South Orkneys is interesting, as considerably widening its geographical area.

*Yoldia eightsi* (Couth.).

*Nucula eightsi*, Couthouy; *vide* Jay, *Cat. Shells*, 1839, ed. iii., p. 113, pl. i., figs. 12, 13.
*Leda* (*Yoldia*) *eightsi*, Hanley, in Sowerby's *Thes. Conch.*, vol. iii., p. 142, pl. ccxxx., fig. 164.
*Yoldia eightsi*, Sowerby, *Conch. Icon.*, vol. xviii., pl. v., fig. 26.

*Hab.*—Station 325, Bay A, South Orkneys, at 9–10 fathoms, May 1903. Scotia Bay, at $\frac{1}{2}$ to $1\frac{1}{2}$ fathoms, December 18, 1903; and again at 6 fathoms, February 1, 1904.

Most examples were dredged on the latter occasion.

### Order FILIBRANCHIATA.

### Sub-order ANOMIACEA.

### Family *Anomiidæ*.

*Anomia ephippium*, L.

*Anomia ephippium*, Linné, *Syst. Nat.*, xii. ed. (1769).
„ „ Jeffreys, *Brit. Conch.*, vol. ii., p. 30, pl. i., fig. 4.
„ „ Smith, *Report "Challenger" Exp.: Zool.*, xiii., p. 318.

*Hab.*—Gough Island, trawl, at 100 fathoms.

The specimens are all in young condition, and may possibly be an allied species; but we can see no difference when compared with juvenile examples of this well-known

*ephippium*. We are corroborated in our opinion by its having been noted in the Tristan d'Acunha group (Nightingale Island) during the *Challenger* Expedition.*

Sub-order ARCACEA.

Family *Arcadæ*.

*Arca* (*Bathyarca*) *strebeli*, sp. n. (Plate, figs. 13, 13*a*).

A. testa parva, orbiculata, paullum inæquilaterali, æquivalvi, alba, epidermide tenui, olivacea, fibrosa, prædita, radiatim tenuissimé arctilirata, lineis concentricis incrementalibus irregulariter cancellata, latere antico abbreviato, postico laté rotundato, margine dorsali feré recto, deinde marginem apud ventralem leniter rotundato, umbonibus prominulis, obtusis, contiguis, conspicuis, dentibus parvis ad 18, pagim interna alba, marginibus lævibus.

Alt. 4·5, lat. 5, diam. 4 mm.

*Hab.*—Trawl, Station 291, lat. 67° 33′ S., long. 36° 35′ W., 2000 fathoms March 7, 1903.

Allied to *A. inæquisculpta*, Sm. (*Rep. "Challenger" Exp.*, xiii., p. 267, pl. xvii., figs. 8–8*c*), but differing from that species and its allies, *A. pectunculoides*, Scacchi, *A. frielei*, Jeffreys, and *A. anaclima*, Melv.,† in its rounder outline, more prominent umbones, and greater delicacy of texture. It is slightly larger than *A. imitata*, Sm. (*l.c.*, p. 321, figs. in text), which seems a very variable form, dredged in the North Pacific Ocean, lat. 35° 22′ N., long. 169° 53′ E., at 2900 fathoms. This last is a coarser shell than *A. strebeli*, but its nearest congener, in our opinion. It gives us pleasure to connect with this interesting benthal species the name of Dr HERMANN STREBEL, who was good enough to examine it, and give us his opinion concerning it.

*Lissarca notorcadensis*,‡ sp. n. (Plate, figs. 14, 14*a*).

L. testa parva, rotundo- vel ovato-trapezoide, solidiuscula, sordidé alba, æquivalvi, inæquilaterali, interdum epidermide fugaci, tenui, olivacea, pallida, partim tecta, undique concentricé arcté striata, umbonibus obtusis, feré contiguis, ligamento partim externo, anticé angusta, posticé expansa, marginem ad ventralem rotundata, pagina interna alba, lævigata, marginibus pulchré crenulatis, dentibus ad 10, utrimque divergentibus.

Alt. 5, lat. 6, diam. 2·75 mm.

*Hab.*—Off weed, and attached to Bryozoa, etc., Station 325, Scotia Bay, South Orkneys, 9–15 fathoms; also in same bay, April–June 1903, June 1904.

A proportionately thick, smoothish, white *Lissarca*; some examples roundly, others (and more generally) ovately trapezoid; larger as a rule than *L. rubrofusca*, Smith, which was found with it. The whole surface is closely concentrically striate. Within, the margins are crenulate; the teeth, five on each side of the hinge-plate, divergent.

*Lissarca rubrofusca*, Smith.

*Lissarca rubrofusca*, E. A. Smith, *Phil. Trans. Royal Soc.* (1879), vol. clxviii., p. 185, pl. ix. fig. 17.

" " E. von Martens and G. Pfeffer, *Mollusken von Süd-Georgien*, 1886, p. 128, Taf. iv., fig. 14 *a–e*.

* *Rep. "Challenger" Exped.*, xiii., p. 318.

† *Proc. Zool. Soc. Lond.* (1907), i., p. 794, pl. liv., fig. 6.

‡ νότος Ὀρκάδες, from the locality.

*Hab.*—Scotia Bay, South Orkneys, 9–10 fathoms, April 1903. Station 325, contiguous to first-mentioned locality, off weed, dredged August 1903. Likewise in shore pools, Scotia Bay, December 1903. All seemingly typical.

## Sub-order MYTILACEA.

### Family *Mytilidæ*.

#### *Mytilus edulis*, L.

*Mytilus edulis*, Linné, *Syst. Nat.*, xii. ed., p. 1157 (1769).
„ „ Forbes and Hanley, ii., p. 170, pl. xlviii., figs. 1–4.
„ „ Jeffreys, *British Conchology*, ii., p. 104 (1863).
„ „ Smith, *Phil. Trans. Roy. Soc. Lond.*, vol. clxviii., p. 189 (1879).

*Hab.*—Hearnden Water, Falkland Islands, 1903.

This abundant European species is fast becoming almost universal outside the actual tropics. It was included by Mr E. A. SMITH (*vide* the reference given above) as occurring in Kerguelen Island, and it is also reported from New Zealand.

#### *Mytilus magellanicus*, Chemnitz.

*Mytilus magellanicus*, Chem., *Conch. Cat.*, vol. viii., pl. lxxxiii., fig. 742.
„ „ Reeve, *Conch. Icon.*, vol. x., pl. vi., fig. 22.

*Hab.*—Port William and Port Stanley, 6 fathoms, January 1904; also on shore, Cape Pembroke, Falkland Islands.

#### *Mytilus ovalis*, Lamarck.

*Mytilus ovalis*, Lam., *Enc. Méth.*, pl. ccxix., fig. 3.
„ „ Reeve, *Conch. Icon.*, vol. x., pl. iv., sp. 14.

*Hab.*—Hearnden Water, Falkland Islands, January 7, 1903.

#### *Philobrya meridionalis* (Smith).

*Mytilus meridionalis*, Smith, *Report*, "*Challenger*": *Lamellibranchiata*, vol. xiii., pp. 273, 274, pl. xvi., figs. 3, 3*a*.

*Hab.*—Station 325. Dredged at 9–15 fathoms, Scotia Bay, South Orkneys, May 1903.

Originally described from a station between Kerguelen and Heard Islands, at 150 fathoms, and, at about the same depth, from Prince Edward Island.

#### *Philobrya quadrata* (Pfeffer).

*Philippiella quadrata*, Pfeffer; E. von Martens and G. Pfeffer, *Mollusk. von Süd-Georgien*, 1886, p. 119, Taf. iv., fig. 6 *a-b*.

*Hab.*—Shore pools, Scotia Bay, South Orkneys.

*Philobrya wandelensis*, E. Lamy.

*Philobrya wandelensis*, Ed. Lamy, *Exp. Ant. Franç. Charcot*, 1903–5, p. 16, pl. i., figs. 15, 16.

*Hab.*—Scotia Bay, South Orkneys. Dredged, 6 fathoms, February 1, 1904.

*Modiolarca mesembrina*,* sp. n. (Plate, figs. 15, 15*a*).

M. testa parva, ovato-trapezoide, nigro-brunnea, tenui, convexa, æquivalvi, inæquilaterali, umbonibus prominulis, paullum incurvis, obliquis, interdum partim erosis, superficie omni epidermide nigrescente contecta, sub lente radiatim longitudinaliter decorata, anticé compressa, posticé rotundata, dente cardinali in utraque valva prædita, pagina interna brunnea.

Alt. 4, lat. 4, diam. 2 mm.

*Hab.*—Shore, Port Stanley, Falkland Islands.

We cannot exactly match this with any of the known species.

Order PSEUDOLAMELLIBRANCHIATA.

Family *Pectinidæ*.

*Pecten colbecki*, Smith.

*Pecten colbecki*, E. A. Smith, "*Southern Cross*" *Ant. Exp.* (1902), Brit. Mus. Publ., p. 212, pl. xxv., fig. 11.

*Hab.*—Lat. 64° 48′ S., long. 44° 26′ W., at 2485 fathoms, March 13, 1903.

Fragmentary portions of the left valve only, the equal auricles being perfect, and a great part of the central superficies. This valve is flattened, and exhibits about fifteen ribs, somewhat uneven. There is uniform, close concentric striation. Colour, cinereous white suffused with dull rose-pink, with purplish tinge. Mr EDGAR SMITH described this species from a single right valve. The substance is so thin and papyraceous that it can be bent to a certain extent without injury.

*Pecten multicolor*, sp. n. (Plate, figs. 21, 21*a*).

P. testa delicata, mediocri, tenui, inæquilaterali, æquivalvi, planato-convexiuscula, variis coloribus ornata, nunc flavida, nunc pallidé violacea, interdum rufescente, vel alba, interdum pulchré maculata, auriculis valde inæqualibus, posticis radiantibus, radiis arcté squamatis, anticis tenui-costatis, æqué squamatis, valva sinistra costis ad 22, lævibus, in statu juvenili pulcherrimé squamatis, deinde lævissimis, paullum irregularibus, interstitiis 5-seriatim arctissimé scobinatis, asperulatis, valva dextra costis arctis ad 50, interstitiis interdum planatis, interdum una serie squamarum scobinata decorata, umbonibus acutis, sublævibus, pagina interna radiatim sulculosa.

Alt. 21, lat. 19, diam. 5 mm. spec. maj.
„ 16, „ 14, „ 3 „ „ min.

*Hab.*—Gough Island.

A very delicate *Pecten*, variously coloured, in which the ribs and interstices of the

* μεσέμβρινος, southern.

left valve, especially, exhibit much elaboration of sculpture. When young, round, shining, very fugitive scales exist, especially towards the ventral margin, whilst the interstices are closely scobinate, there being four or five closely imbricate rows of minute squamæ. The right valve is by no means so elaborate, while the radiating ribs, irregularly placed, are more than double in number, not, indeed, leaving much space for interstitial development.

Doubtless allied to *P. limatula*, Reeve,* and others of that section, the right valve, indeed, is hardly separable in sculpture from that of *limatula*; but its fellow is more elaborately sculptured with close rows of interstitial scales than is the case in that species, which is reported from Nightingale Island, Tristan d'Acunha (*Rep. "Challenger" Exped.*, xiii., p. 297, pl. xxi., figs. 5, 5*a*).

*Pecten* sp.

A right valve of *Pecten* sp., the auricles very detrite, covered with small *Balani*, *Membranipora*, and other growths both without and within, but exhibiting about 35 variable, on the whole distinct, clearly cut, narrow longitudinal ribs, may be a form of *P. patagonicus*, King.

*Hab.*—Port William, Falkland Islands. Trawled at 6 fathoms.

*Pecten pteriola*, sp. n. (Plate, figs. 16, 16*a*).

P. testa parva, inæquivalvi, inæquilaterali, albo-cinerea, obliquante, valva dextra minore, haud nitente, concentricé rudi-striata, aliter lævi, auricula valvæ hujus solum antica, lata, tenuisculpta, valva sinistra convexa, arctissimé liris concentricis incrementalibus lamellatis prædita; interstitiis feré obtectis, umbone dextræ acuto, incurvo, margine dorsaliter utrimqué æquali, recto, deinde apud marginem ventralem obliqué leniter rotundato. Pagina intus alba, nitida.

Alt. 4, lat. 4·5, diam. 1·5 mm.

*Hab.*—Station 325. Dredged in Scotia Bay, South Orkneys, April 1903, at 9–10½ fathoms.

The nearest approach to this particularly interesting little *Pecten*, of which several examples, all precisely similar, occurred, is *P. aviculoides*, Sm. (*Rep. "Challenger" Exp.: Lamellibr.*, xiii., p. 325, pl. xxii., figs. 5, 5*a*). It is, however, not only double the size of that minute form, but also very differently sculptured, the ribs, so characteristic on the left valve of the *Challenger* species, which came from Prince Edward Island, being absent, and replaced by closely laminate concentric ridges or liræ. The specific name is chosen from the likeness to species of *Pteria*, Scop. (= *Avicula*, Lam.) in miniature.

*Amussium octodecim-liratum*, sp. n. (Plate, figs. 17, 17*a*).

A. testa compressa, albo-lactea, subpellucida, tenui, rotunda, feré æquilaterali, inæquivalvi, valvis diversé sculptis, dextra pulcherrimé cancellata, striis multis erectis concentricé radiantibus, simul ac arctissimé longitudinaliter striatula, interstitiis quadratulis, valva sinistra delicaté et arctissimé concentricé striata, auriculis utrimque feré æqualibus, tenuisculptis, umbonibus ambobus acutis, subprominulis, pagina interna alba, nitida, liris in valvâ utraque octodecim, ad margines extensis, prædita.

Alt. 9, lat. 11, diam. 2·5 mm.

*Hab.*—Station 291, lat. 67° 33′ S., long. 36° 35′ W., trawl, 2500 fathoms.

* Reeve, *Conch. Icon.*, viii., pl. xxviii., fig. 124.

A very thin, milky-white, delicately papyraceous *Amussium*, the valves almost equilateral, slightly unequal, auricles subequal, straight, finely sculptured; the left valve beautifully concentrically radiately striate, the striæ very close and fine; and the right with finely cancellate upright striæ, with quadrate interstices. Within, each valve exhibits an equal number of strong lirations, say 18, whence the specific name.

Family *Limidæ*.

*Lima* (*Mantellum*) *goughensis*, sp. n. (Plate, figs. 18, 18*a*).

L. testa alba, mediocri, convexa, obliquata, ovato-oblonga, æquivalvi, superficie omni longitudinaliter et regulariter multi-lirata, liris ad 48, interstitiis longitudinaliter sub lente per medium æqui- et unistriatis, lineis concentricis incrementalibus spiraliter prædita, umbonibus incurvis, margine dorsali feré recto, area ligamentari lata, centrali, pagina intus alba, longitudinaliter striatula, margine ventrali minuté serrulato.

Alt. 10, lat. 7, diam. 8 mm. sp. maj.

*Hab.*—Trawl, 100 fathoms, Gough Island, April 23, 1904.

A small species, if our specimens be adult. Although ordinary in form, with valves very convex and trapezoidly oblique, yet the delicate and regular longitudinal liræ, each with an accompanying single interstitial corresponding stria, seem characteristic.

*Lima* (*Limatula*) *pygmæa*, Philippi.

*Lima pygmæa*, Philippi, Weigmann's *Archiv f. Naturgesch.* (1845), p. 56.
*Limatula falklandica*, A. Adams, *Proc. Zool. Soc. Lond.* (1863), p. 509.
*Radula* (*Limatula*) *pygmæa*, Smith, *Phil. Trans. Roy. Soc.* (1879), vol. clxviii., p. 191.
*Lima* (*Limatula*) *pygmæa*, Phil.; Smith, *Report "Challenger" Exp.: Zool.*, xiii., p. 292.

*Hab.*—Station 325. Dredged in Scotia Bay, South Orkneys, at 9–10 fathoms, April 1903; and again, South Orkneys, at 2–8 fathoms, December 1, 1903. Likewise in Macdougal Bay, South Orkneys.

Order EULAMELLIBRANCHIATA.

Sub-order SUBMYTILACEA.

Family *Lucinidæ*.

*Cryptodon falklandicus*, Smith.

*Cryptodon falklandicus*, A. E. Smith, *Rep. "Challenger" Exp.: Zool.*, xiii., p. 190, pl. xiv., figs. 3, 3*a* (1885).

*Hab.*—Scotia Bay, South Orkneys. Dredged at 9–10 fathoms, September 1903.

In every way agreeing with the type. One specimen only, but perfect. This species has also occurred at Shallow Bay, Lively Island, Falklands * (Miss COBB).

* *J. of Conch.*, ix., p. 105.

*Cyamium antarcticum*, Phil.

*Cyamium antarcticum*, Philippi, *Arch. Naturg.* (1845).
" " H. and A. Adams, *Gen. Rec. Moll.*, ii., p. 476, pl. cxiv., fig. 11 *a*, *b* (1858).
Chemn., *Man. de Conch.*, ii., p. 127, fig. 605.

*Hab.*—Shore, Falkland Islands, January 1903.
Only in young state, but perfect specimens.

*Cyamium falklandicum*, M. & St.

*Cyamium falklandicum*, Melvill and Standen, *Journ. of Conch.*, ix., pl. i., fig. 12 (1898).

*Hab.*—Shore, Hearnden Water, Falkland Islands, January 1, 1903.
Only in juvenile condition, occurring with the last-named species. The surface is mostly beautifully iridescent in these specimens.

Family *Erycinidæ*.

*Lasæa consanguinea* (Smith).

*Kellia consanguinea*, E. A. Smith, *Phil. Trans. Roy. Soc.*, vol. clxviii., p. 184, pl. ix., fig. 20 (1879).

*Hab.*—Hearnden Water, Falkland Islands, January 7, 1903; Scotia Bay, South Orkneys, 6–10 fathoms, February 1, 1904.
Near *L. miliaris*, Phil., but apparently distinct. Varying somewhat in colour, from a uniform deep rose tint to straw-coloured, tinged with rose only at the dorsal margin.

*Kellia cycladiformis* (Desh.).

*Erycina cycladiformis*, Deshayes, *Trait. élém.*, pl. xi., figs. 6–9; *P.Z.S. Lond.*, 1855, p. 181.

*Hab.*—Burdwood Bank, trawl, 56 fathoms, December 1903.
A species of wide distribution in southern latitudes. Reported from North Australia (Jukes), New Zealand (Quoy, Hutton, Hector), etc.

*Kellia lamyi*, nom. nov.

*Kellyia australis*, E. Lamy, "Moll. des Orcades du Sud," *Bull. Mus. Hist. Nat. Paris*, 1906, p. 124 (non Deshayes).

*Hab.*—Scotia Bay, South Orkneys. Dredged at 6 fathoms.
A minute species, which occurred gregariously in great numbers at the above station. Its obliquely ovate form, when seen with the valves closed, somewhat recalls a *Nucula*. In the left valve the single cardinal tooth is flanked by two very prominent incrassate laterals. In some specimens there is corrosion at the umbones. We have renamed

this species in honour of M. EDOUARD LAMY, its original describer, the specific name he selected having been already employed by M. DESHAYES.

? *Scacchia plenilunium*, sp. n. (Plate, figs. 20, 20*a*).

Sc. testa parva, elliptico-rotunda, convexa, nitida, albida, epidermide pallidé olivacea, omnino contecta, lævigata, striis concentricis incrementalibus exceptis, apud umbones obtusos nequaquam prominulos, crassiore, marginibus feré rotundis, margine dorsali intus pluteato, ligamento partim interno, dentibus lateralibus in valve utraque utrinque extensis, pagina interna pallidé cinerea.

Alt. 4, lat. 4·5, diam. 2 mm.

*Hab.*—Shore, Cape Pembroke, Falkland Islands.

A small, rounded, somewhat convex shell, with shining pale olive epidermis, smooth, save for the concentric lines of growth. We are not sure of its genus; but in some respects it possesses affinity to the European *Scacchia elliptica*, Phil. Within, the inner side of the dorsal margin protrudes as a kind of flattened narrow shelf or buttress in both valves, the extended lateral teeth being placed at either extremity of it. (*Plenilunium*, a full moon, from the rounded form.)

Sub-order TELLINACEA.

Family *Tellinidæ*.

*Tellina* (*Mæra*) *pusilla* (Philippi).

*Tellina pusilla*, Phil., *Moll. Sic.*, i., p. 29, t. iii., fig. 9 *a*, *b*.
„ *pygmæa*, "Phil."; Lovén, in Forbes and Hanley, i., p. 295, pl. xix., figs. 6, 7.

*Hab.*—Shore, Gough Island, April 22, 1904.

Only one half valve, but perfect, and coloured with rose radiations. We cannot separate it from the British species, which apparently has a wide range in the eastern tropics. It occurs, for instance, in the Persian Gulf, and on the Mekran Coast; and this occurrence at Gough Island shows a further extension of its range southward in the Indian Ocean.

Sub-order VENERACEA.

Family *Veneridæ*.

*Chione philomela* (Smith).

*Venus philomela*, E. A. Smith, *Report "Challenger" Exp.: Lamillibr., Zool.*, xiii., p. 117, pl. ii., figs. 7, 7*b* (1885).

*Hab.*—Trawl, Gough Island, at 100 fathoms, April 23, 1904.

Only small, dead, and imperfect examples. Originally described from Nightingale Island, one of the Tristan d'Acunha group, and within measurable distance of Gough Island.

*Tapes* (*Amygdala*) *exalbida* (Chem.).

*Venus exalbida*, Chemnitz, *Conch. Cat.*, vol. xi., p. 220, pl. ccii., fig. 1974.
„ „ Reeve, *Conch. Icon.*, vol. xiv., fig. 13.
„ „ Sowerby, *Thes. Conch.*, vol. ii., p. clxi., fig. 193.
*Chione exalbida*, Deshayes, *Cat. Conchif. Mus. Brit.*, p. 154.
„ (*Omphaloclathrum*) *exalbida* (Chem.), Paetel, *Catal.*, iii., p. 85.
*Tapes* (*Amygdala*) *exalbida* (Chem.), E. A. Smith, *Rep.* "*Challenger*" *Exped.: Lamellibr.*, xiii., p. 117.

*Hab.*—Port William, Falkland Islands, trawl, January 31, 1904.

Sub-order MYACEA.

Family *Glycimeridæ*.

*Saxicava arctica* (L.), var. *antarctica*, Phil.

*Mya arctica*, Linné, *Syst. Nat.*, p. 1113.
*Saxicava arctica* (L.), Forbes and Hanley, i., p. 141, pl. vi., figs. 4–6.
„ *antarctica*, Phil., *Archiv f. Naturg.*, 1845.

*Hab.*—Gough Island, trawl, 100 fathoms, April 23, 1904; Burdwood Bank, trawl, 56 fathoms, December 1, 1903.

We consider *S. antarctica*, Phil., by which name some would designate this protean species, merely as a synonym, or, at most, varietal, there being no salient characters which can be discerned by us as warranting their distinctness.

Sub-order ANATINACEA.

Family *Lyonsiidæ*.

[*Lyonsia cuneata* (Gray).

Of this or a nearly allied species a single specimen, hardly adult, was found after a gale in a stranded root of the giant *Macrocystis*, at Port Stanley, Falkland Islands, February 5, 1904. It has sometimes been considered an *Entodesma* or *Mytilimeria*.]

Family *Anatinidæ*.

*Anatina elliptica*, King and Brod.

*Anatina elliptica*, King and Broderip, *Zool. Journ.*, vol. v., p. 325.
„ „ Reeve, *Conch. Icon.*, xiv., fig. 14.
„ „ Griffiths, *Anim. Kingd.*, xii., pl. xxii., fig. 3.
„ „ Smith, *Rep.* "*Challenger*" *Exp.: Lamell., Zool.*, xiii. (1885), p. 76.
„ „ „ "*Southern Cross*" *Moll.*, p. 210, pl. xxv., figs. 9, 10.
„ „ „ *Nat. Antarct. Exped.*, vol. ii. (Brit. Mus. N.H.), p. 1, pl. iii., fig. 3 (1907).
„ *prismatica*, Sowb., *P. Z. Soc. Lond.*, p. 87 (1834).

*Hab.*—Station 325, Scotia Bay, South Orkneys. Dredged at 9–10 fathoms.

A large, well-grown example. Smaller examples from the same locality, these last

partially covered with bright green, somewhat shining epidermis. Mr SMITH's figures of this species, references to which are given above, illustrate two extremes of form admirably.

Order SEPTIBRANCHIATA.

Family *Cuspidariidæ*.

*Cuspidaria brucei*, sp. n. (Plate, figs. 19, 19*a* and *b*).

C. testa pro genere magna, ovata, tenui, papyracea, nitida, superficie omni delicaté concentricé irregulariter lamellato-striata, inæquilaterali, feré æquivalvi, convexa, umbonibus maximé contiguis, paullum inter se erosis, margine postico dorsaliter feré recto, deinde subrostrato, ventrali, cum margine antico, leniter rotundato. Pagina intus alba, lactea, nitida, dente cardinali in valva sinistra parvo, centrali, in dextra laterali lato, extenso, fossa ligamentari obliqua, parva.

Alt. 17, lat. 26·5, diam. 10 mm.

*Hab.*—Lat. 39° 48′ S., long. 2° 33′ E., 2645 fathoms.

A very conspicuous, creamy-white, shining *Cuspidaria*, of papyraceous texture, of which only one example was dredged from the deep sounding given above. The posterior rostrum is abbreviate, the shell otherwise being gently rounded in the fore part. The umbones are close together, and detrite owing to friction. Within, the surface is pure, shining white, showing traces of the external concentric lamellar striation. We should place this species in the typical section of the genus (*vide* SMITH, *Rep. "Challenger" Exped.*, vol. xiii., pp. 35–39; and DALL, *Bull. Mus. Comp. Zool. Harvard*, vol. xii., pp. 292 *sqq.*). To Mr W. S. BRUCE, F.R.S.E., this beautiful addition to the genus is dedicated.

B.—AT ASCENSION ISLAND.

*Lotorium grandimaculatum* (Reeve) [*Triton*].

*Hab.*—Ascension Island, net, 18 fathoms, June 9, 1904.
Now considered a var. of *L. lotorium* (L.).

*Nerita* (*Thelicostyla*) *ascensionis*, Gmel.

*Hab.*—Ascension Island Harbour, dredge, 25 fathoms.
Good examples of this usually worn species, in various stages of growth.

C.—AT SALDANHA BAY, SOUTH AFRICA.

*Chætopleura papilio* (Spengler).

*Hab.*—Two fine specimens from coaling jetty, Capetown Docks.

*Ischnochiton tigrinus* (Krauss).

*Hab.*—Shore, Hontjes Bay, Saldanha Bay.

*Chiton nigrovirens*, Blainville.

*Hab.*—Shore and trawl, Hontjes Bay and Saldanha Bay.

*Acanthochites Garnoti*, Blainville.

*Hab.*—Trawl, False Bay, May 8, 1904; Hontjes Bay, shore, and trawl; Saldanha Bay, shore and trawl.

A fine and well-known species.

*Bullia annulata* (Lam.).

*Hab.*—Trawl, Saldanha Bay, 9–10 fathoms.

*Bullia lævigata*, Chem. [*lævissima*, Gmel.].

*Hab.*—Shore, Hontjes Bay, Saldanha Bay, May 20, 1904.

*Mytilus edulis*, L., var. *meridionalis*, Krauss.

*Hab.*—Trawl, Saldanha Bay, 25 fathoms.

*Mytilicardia* (*Thecalia*) *concamerata* (Brug.).

*Hab.*—Shore, Hontjes Bay, Saldanha Bay, 25 fathoms

*Tapes pullastra* (Montagu).

*Hab.*—Trawl, Saldanha Bay, 25 fathoms.

We cannot separate the several examples, all perfect, that were gathered at the above locality, from the European species. It is also recorded by Krauss, from Natal and Algoa Bay.*

*Oxystele impervia*, Menhe.

*Oxystele tigrina*, Chem.

*Hab.*—Trawl, 25 fathoms, Saldanha Bay; *O. tigrina* also occurring at Hontjes Bay.

*Crepidula hepatica*, Desh.

*Hab.*—Trawl, 25 fathoms, Saldanha Bay.

*Gyrineum* (*Argobuccinum*) *argus* (Gmel.).

*Hab.*—Hontjes and Saldanha Bays, 5–15 fathoms.

*G. vexillum* (Sowb.) seems synonymic.

*Phos plicosus*, Dunker.

This, which is the *Nassa speciosa* (A. Ad.), is a handsome species with certain characteristics of both genera, the Nassoid element, in our opinion, prevailing. We should therefore be inclined to restore it to the genus *Nassa*.

* *Vide* G. B. Sowerby, *Marine Shells of South Africa*, p. 59 (1892).

*Hab.*—Trawl, Reitz Bay, trap, 5 fathoms; and in Saldanha Bay, 5 fathoms, May 20, 1904.

*Cominella limbosa* (Lam.).

*Hab.*—Trawl, Saldanha Bay, 25 fathoms; and shore, Hontjes Bay.

*Patella compressa*, L., var. *miniata*, Born.

We cannot dissociate this species from *P. umbella*, Gmelin. It is a species that varies its form in accordance with its habitat.

*Hab.*—Trawl, 25 fathoms, Saldanha Bay, May 21, 1904.

*Patella* (*Scutellastra*) *granatina*, L.

*Hab.*—Shore, Hontjes Bay.

*Patella* (*Scutellastra*) *oculus*, Born.

With the last. These two handsome and similar species possess well-defined characters differentiating them from each other, but, though they usually occur together, have not yet been noticed to hybridise.

*Helcion pectinatum* (Born.).

*Hab.*—Shore, Hontjes Bay, Saldanha Bay.

*Fissurella mutabilis*, Sowerby.

*Hab.*—Trawl, 25 fathoms, Saldanha Bay.

*Megatebennus scutellum* (Gmelin).

*Hab.*—Trawl, Saldanha and Hontjes Bays.

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## EXPLANATION OF PLATE.

1. *Tugalia antarctica.*
2. *Littorina* (*Lævilitorina*) *coriacea.*
3, 3*a*. *Lacuna notorcadensis.*
4. *Rissoa edgariana.*
5. ,, *scotiana.*
6, 6*a*. *Cerithiopsis malvinarum.*
7, 7*a* *Trophon minutus.*
8, 8*a*. *Nassa* (*Ilyanassa*) *vallentini.*
9. *Chrysodomus* (*Sipho*) *archibenthalis.*
10, 10*a*. ,, ,, *crassicostatus.*
11*a*. *Columbarium benthocallis.*
12. *Dentalium eupatrides.*
13, 13*a*. *Arca* (*Bathyarca*) *Strebeli.*
14, 14*a*. *Lissarca notorcadensis.*
15, 15*a*. *Modiolarca mesembrina.*
16, 16*a*. *Pecten pteriola.*
17, 17*a*. *Amussium octodecim-liratum.*
18, 18*a*. *Lima* (*Mantellum*) *gouyhensis.*
19, 19*a*, 19*b*. *Cuspidaria brucei.*
20, 20*a*. *? Scacchia plenilunium.*
21, 21*a*. *Pecten multicolor.*

MELVILL AND STANDEN: MARINE MOLLUSCA.

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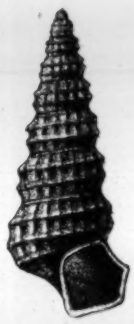
2.

3.

4.

5.


6.

6a.

3a.

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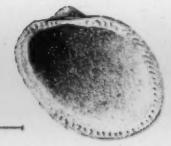
14a.

15.

15a.

16.

16a.

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17a.

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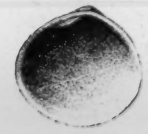
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# VI.—The Pycnogonida of the Scottish National Antarctic Expedition. By Mr T. V. Hodgson, F.L.S. *Communicated by* Dr R. H. Traquair, F.R.S. (With Three Plates.)

(MS. received July 12, 1907. Read July 15, 1907. Issued separately January 24, 1908.)

I am greatly indebted to Dr W. S. Bruce, the able leader of the Scottish National Antarctic Expedition, for the opportunity to describe the *Scotia* collections as regards the Pycnogonida and the Isopoda. We are now concerned with the Pycnogonida, and I regret that there has been so much delay before the production of the report. The collection is a large one, and extremely interesting—totally different from that made by the *Discovery* in the same region, but on the opposite side of the world. If smaller in the number of species brought home, in number of individuals it far exceeds that collection. Its principal interest lies in problems of distribution.

First and foremost, there is the exceptionally interesting and important species *Decolopoda australis*, Eights (8), a species discovered and accurately described some seventy years ago, but forgotten, and, when first noticed, despised as a monstrosity or as a sample of defective work. For the present its relations must remain more or less conjectural. It is unquestionably a very close ally of the genus *Colossendeis* (12). Though it is early yet to make a positive assertion on the subject, it appears to share with that genus the capacity for depositing its eggs in some unknown hiding-place. The ova of both genera are unknown, and it is certain that in *Colossendeis* at least they are not carried by the male, or in fact by either sex. *Decolopoda* would appear to be abundant in the South Shetland and South Orkney Islands, and a second very closely allied species has been taken from the west coast of Graham's Land (Carthage Bay) by the French Antarctic Expedition.

The second announcement of the discovery of a Pycnogonid with five pairs of legs, *Pentanymphon antarcticum*, was made by myself as one of the results of the *Discovery* Expedition (10). In the present collection there is only a single individual of this species, and that an adult female; but it has also been captured by the French and German Expeditions. It may be said to have a circumpolar distribution, and lives at a depth of from 10 fathoms to just over 200.

For the rest of the collection, there are several new species, none of which, however, can be placed in new genera.

*Pallenopsis* has a new species very closely allied to the *P. pilosa* of Hoek, but distinguished by spurs on the lateral processes and legs. Dr Hoek's species is, moreover, a deep-water form, while this one comes from inside the 10-fathom line.

*Nymphon* contains three species from the Antarctic, and another, a new species, from

the African coast. Of the Antarctic species, two are identical with species taken by H.M.S. *Challenger* off New Zealand in 1100 fathoms (Station 168). *N. longicoxa* was taken in 1410 fathoms, lat. 71° 22′ S., long. 16° 34′ W.; and *N. compactum* was taken in 1775 fathoms, lat. 62° 10′ 5″ S., long. 41° 20′ W. The great distance from the point of their original discovery is well worthy of note, as well as the increase of depth.

*Chætonymphon* contains four species with some interesting facts in distribution. *C. orcadense* is described as a new species, and was taken in Scotia Bay in immense numbers, and a single specimen from the Burdwood Bank, off the Falkland Islands. At first sight it is like *C. australe*, Hodgson, but is readily distinguished by the distinct auxiliary claws. *C. assimile* is a new species of which there are many specimens in the collection. This one and *C. australe* and *C. altioculatum*, Möbius, are all very closely allied. In my report on the *Discovery* collection I stated that I was unable to regard *C. altioculatum* as distinct from *C. australe*. *C. austrinorum* I regarded as a variety of *C. australe*, though a well-marked one. These four species or varieties, whichever they may be, differ more definitely in their setose covering than in any other particular. I have no reason to modify my opinion on their specific differences; but with regard to *C. altioculatum*, Möbius, there is most room for doubt. Examination of the type specimens reveals the fact that there is a fringe of small setæ at the posterior border of the trunk segments. This feature is not very prominent, and is not brought out by Professor Möbius' description; and if this is not to be regarded as a specific character, it has a certain value when the variation and distribution of species are under consideration. All the other peculiarities of the animal agree closely with those ascribed to *C. australe*, and one does not feel justified in separating the two as distinct species. No specimens of *C. australe* or this particular variety occur in the *Scotia* collection, but a very close relation exists in *Chætonymphon assimile*, which is described as a distinct species. It is readily distinguished by the setose character of its body, which is devoid of setæ, except for a few long ones as a distal fringe on the lateral processes; other features show that it may be regarded as distinct, though closely allied.

An important bond of union between all these species is the tall ocular tubercle, which caused Professor Möbius to derive the name of his species from that organ. One specimen of *C. assimile* and another of *C. orcadense* have two fairly well-developed eyes on one side of the tubercle, in addition to the four at the summit.

A purely sexual feature lies in the fact that in *C. australe*, *C. austrinorum*, *C. altioculatum*, and *C. assimile* the ovigers of the adult male all have the fifth joint abruptly expanded to more than double its diameter for its distal half; the following joint also is considerably enlarged, but most so proximally. Another is the enormously developed distal fringe which occurs ventrally on the third coxæ of the two posterior pairs of legs in the male.

*C. mendosum* is not uncommon in Scotia Bay at 10 fathoms; at the other side of the hemisphere, and farther south by 16°, the *Discovery* found it equally abundant, but only below the 100-fathom line.

*C. brevicaudatum*, Miers, only previously known from Kerguelen, now extends its range to Scotia Bay.

*Ammothea.*—Two individuals of a single species of this genus were found, and are identified with Professor BOUVIER's *A. communis*, which was found in great numbers by the *Français* on the west side of Graham's Land. The members of this genus appear to be abundant in the Magellan Province, but none were seen by the *Discovery* in M'Murdo Sound.

*Leionymphon* is a genus instituted by Professor MÖBIUS for some immature specimens found off Bouvet Island. The collection of the *Discovery*, which was rich in these forms, necessitated a revision of the genus, which now includes no less than eight species, a key to which is given in my report on that collection (13). The two species included in the present collection were described many years ago by Dr G. PFEFFER, under the generic name of *Ammothea*. They were then recorded from South Georgia, and it is only to be expected that they should occur also in the South Orkneys. *L. grande*, however, has had its range extended considerably, and evidently has a circumpolar distribution.

*Colossendeis* is represented by two individuals, two very distinct species claiming them. One is a *Challenger* species, *C. leptorhynchus*, and was taken in the area where it was first found. The other is introduced as new; it is quite blind—not an unusual character of the genus, but the more surprising as it is a shallow-water species.

When considering geographical problems during our stay in the Antarctic regions, I accepted the mean annual isotherm of 45° F. for the ocean surface, as defined by Dr A. BUCHAN (4) in the concluding volume of the "*Challenger*" *Reports*, as the northern limit of the Sub-Antarctic region, partly perhaps as a matter of convenience, and partly because it is a natural limit which includes Kerguelen Island and its neighbours, which have, for a long time, been regarded as "Antarctic," and which have become "classical" ground by the work of that expedition. The value of this boundary is emphasised by the fact that Professor PELSENEER (23), when reporting on the Mollusca of the *Belgica* Expedition, and examining the subject exhaustively, fixed on the isotherm of 40° F. for the air in July, and a similar isotherm for the ocean surface, but a minimum and not a mean temperature; for this latter isotherm Sir JOHN MURRAY is the authority. All the three isotherms above quoted are in very close accord, and a little south of lat. 45° S. on the Pacific side, a little above it on the side of the Atlantic and Indian Oceans. As to the boundary between the Sub-Antarctic and the Antarctic regions, I suggested in my report on the Pycnogonida of the *Discovery* that lat. 60° S. might be provisionally regarded as such; it includes all the glaciated lands of the Antarctic continent and the islands connected therewith. A more satisfactory limit would be the *average* limit of pack ice, if a surface phenomenon is to be accepted; otherwise the centre of the trough between the Antarctic continent and the more northern lands would make a natural division, but the position of this trough will for some time at least be a matter of conjecture.

In a recent paper on the Pycnogonids of the Magellan Straits (14) it became necessary to define that area, and I suggested the division of the Antarctic and Sub-Antarctic regions into three provinces corresponding with the continents from which the attack on those regions can be made. The limits are as yet purely arbitrary, being defined by lines of longitude which may not hold good when our zoological knowledge of these regions becomes greater than at present. The division suggested was as follows :—

(1) Magellan Province, long. 20° W. to long. 130° W.
(2) Australasian Province, long. 130° W. to long. 100° E.
(3) Kerguelen Province (African), long. 100° E. to long. 20° W.

The following list contains all the known species of Pycnogonida from the Antarctic and Sub-Antarctic regions—a list which contains some seventy-two species, thirty-four of which belong, as far as at present known, exclusively to the Antarctic area. Thirty of them belong to the Sub-Antarctic region, and of these, seven find their way farther northward. Those marked with an asterisk are contained in the *Scotia* collection.

| | Ant-arctic. | Sub-Ant-arctic. |
|---|---|---|
| *Pycnogonum magellanicum*, Hoek | | × |
| „ *magnirostre*, Möbius | | × |
| *Phoxichilus australis*, Hodgson | × | |
| *Pallene dimorpha*, Hoek | | × |
| *Pseudopallene cornigera*, Möbius | × | × |
| „ *australis*, Hodgson | × | |
| *Pallenopsis patagonica*, Hoek | | × |
| „ *pilosa*, Hoek | × | × |
| „ *fluminensis*, Kröyer | | × |
| „ *glabra*, Möbius | × | × |
| „ *villosa*, Hodgson | × | |
| „ *hiemalis*, Hodgson | × | |
| * „ *lanata* | × | |
| *Anoplodactylus neglectus*, Hoek | | × |
| „ *petiolatus*, Kröyer | | × |
| *Nymphon gracile*, Leach | | × |
| „ *gracilipes*, Miers | | × |
| „ *brachyrhynchum*, Hoek | | × |
| „ *hamatum*, Hoek | | × |
| „ *fuscum*, Hoek | | × |
| „ *meridionale*, Hoek | × | |
| „ *antarcticum*, Pfeffer | | × |
| „ *hiemale*, Hodgson | × | |
| „ *lanare*, Hodgson | × | |
| „ *adareanum*, Hodgson | × | |
| „ *frigidum*, Hodgson | × | |
| „ *tridentatum*, Hodgson | | × |
| * „ *longicoxa*, Hoek | × | × |
| * „ *compactum*, Hoek | × | × |
| * „ *articulare* | × | |
| * *Chætonymphon brevicaudatum*, Miers | × | × |
| „ *villosum*, Hodgson | × | |
| „ *biarticulatum*, Hodgson | × | |
| * „ *mendosum*, Hodgson | × | |
| „ *australe*, Hodgson | × | |
| „ „ var. *austrinorum*, Hodgson | × | |

| | Ant-arctic. | Sub-Ant-arctic. |
|---|---|---|
| * *Chætonymphon orcadense* | × | |
| * „ *assimile* | × | |
| * *Pentanymphon antarcticum*, Hodgson | × | |
| *Leionymphon striatum*, Möbius | | × |
| * „ *grande*, Pfeffer | × | × |
| „ *gibbosum*, Möbius | | × |
| „ *minum*, Hodgson | × | |
| * „ *Clausi*, Pfeffer | × | × |
| „ *australe*, Hodgson | × | |
| „ *glaciale*, Hodgson | × | |
| „ *spinosum*, Hodgson | × | |
| *Ammothea Hoeki*, Pfeffer | | × |
| „ *Wilsoni*, Schimkewitsch | | × |
| * „ *communis*, Bouvier | × | |
| „ *curculio*, Bouvier | × | |
| *Tanystylum styligerum*, Miers | | × |
| „ *Dohrnii*, Pfeffer | | × |
| „ *Chierchiæ*, Schimkewitsch | | × |
| „ *longicaudatum*, Hodgson | | × |
| *Austrodecus glaciale*, Hodgson | × | × |
| *Austroraptus polaris*, Hodgson | × | |
| *Ascorhynchus glaber*, Hoek | | × |
| *Rhyncothorax australis*, Hodgson | × | |
| *Colossendeis gigas*, Hoek | | × |
| * „ *leptorhynchus*, Hoek | | × |
| „ *gigas leptorhynchus*, Hoek | | × |
| „ *megalonyx*, Hoek | | × |
| „ *robusta*, Hoek | | × |
| „ *gracilis*, Hoek | | × |
| „ *australis*, Hodgson | × | |
| „ *glacialis*, Hodgson | × | |
| „ *frigida*, Hodgson | × | |
| „ *rugosa*, Hodgson | × | |
| „ *magellanica*, Hodgson | | × |
| * „ *orcadensis* | × | |
| * *Decolopoda australis*, Eights | × | |
| „ *antarctica*, Bouvier | × | |

Other species taken on the voyage, but from the African coast only :—

*Nymphon capense.* *Discoarachne brevipes*, Hoek.

*Pallenopsis lanata* (Plate II., figs. 4, 4*a*).

*Specific Characters.*—Body well built, with lateral processes widely separated, each with a prominent spur distally and dorsally ; body and appendages richly setose.

Ocular tubercle conical, placed in front of cephalon ; with anterior eyes large, posterior ones much smaller and above them.

Oviger ten-jointed, with simple setæ only ; no terminal claw, differing in the two sexes.

Legs with long terminal claw and small auxiliaries. Spurs on the femora and first tibiæ distally and dorsally.

The Body is fairly robust, with widely separated lateral processes ; these are not very long, slightly dilating, with a strongly developed spur distally, as well as a fringe of long setæ. The segmentation is distinct ; each segment carries a fringe of long setæ along its posterior border.

The Cephalon is long, cylindrical, and carries the ocular tubercle at its anterior extremity. This rather peculiar structure, seen from behind, is stout, conical, and of some considerable elevation ; seen laterally, it is still conical, but the front upper part of the cone is incurved above the anterior pair of eyes, which are very large ; the posterior pair are scarcely half the size, behind and above them.

The Abdomen is long, almost cylindrical, being slightly dilated just beyond the middle. It is directed upwards to some extent, not articulated to the trunk, and provided with a number of fine long setæ.

The length of the body is 10 mm., the trunk only 7 mm., and its extreme width 5 mm.

The Proboscis is nearly as long as the scape of the chelifori, and rises ventrally behind the position of the ocular tubercle. It is cylindrical and completely covered with stiff setæ, which are largest and most conspicuous ventrally and distally.

The Chelifori are well developed, and rise from the anterior border of the cephalon just underneath the ocular tubercle. The scape is long and two-jointed, the joints being subequal in size and covered with rather short stiff setæ, which are more conspicuous as distal fringes. The chela has small fingers turned inwards almost at a right angle to the palm ; the movable one is much the larger, and is without a setose pad at its base. Neither bear teeth. The palm itself is not quite so long as a joint of the scape, and is covered with shorter and stiff setæ.

The Palps are reduced to stout, rounded, setose buttons ; they rise laterally close to the proboscis.

The Ovigers are ten-jointed, and differ very considerably in the two sexes. In the male, the first joint is very small, the second is very much longer and considerably dilated distally ; the third is not half as long as the second, and is articulated at an angle to it, and not in direct continuation ; its outer border is rounded, the inner one

being straight; these two joints bear setæ of varying length on their outer margins. The fourth and fifth are long and slender, slightly curved, the fifth being a little the longer and dilated distally; both are rather scantily covered with short stiff setæ, and the fourth has a large glandular (?) opening near its base.

The fifth joint is quite short and very stout, bent rather than curved, with a thick covering of long setæ on its outer margin. Of the remaining four, which curve in the opposite direction to the preceding joints, the first two are subequal in length, the two last taper, the terminal one being a little the shortest; all these are richly clothed with long setæ of quite a simple character.

In the female this appendage is shorter and quite different in structure. The first joint is very short; the second is about twice as long and dilated distally; the third is about as long as the first, and articulated to the second in a normal manner. The fourth and fifth are longer, the fourth being much stouter and a little longer than the fifth, and about two-thirds the length of similar joints in the male. All these joints are setose, the setæ being small at first, increasing in size and number to the extremity of the fifth. The sixth is scarcely half the length of the fifth; the seventh, again, much smaller; the eighth is longer, and the terminals taper, but differ little in length. All these are plentifully clothed with rather long simple setæ, and chiefly on the ventral side.

The Leg extends to about 40 mm. Of the three coxæ, the first is the shortest, the second as long as the other two together; the proportions of the three following joints are as 9, 8·5, 10. The tarsus is very small, the propodus slightly curved, with a slender terminal claw nearly as long, and two small auxiliaries. The entire appendage is thickly covered with setæ; these, on the dorsal surface more especially, are long and slender; those on the ventral surface are much shorter. In addition to these there are short and fine setæ distributed uniformly over the whole limb. As usual, the setæ on the second tibiæ become more spinous distally, and the distal fringe of this joint is distinctly spinous ventrally. The ventral surface of the tarsus bears spinous setæ which become very prominent distally. The propodus bears three stout spines proximally and ventrally, the remainder of the surface being occupied by a band of spinous setæ. There is no projecting heel, but a well-developed distal fringe projects over the base of the claw. The femora and first tibiæ of both sexes bear a prominent spur distally and dorsally. The lateral line is distinct.

The Genital apertures of the male occur on conspicuous swellings of the second coxæ of the two posterior pairs of legs. About the middle of the femur, ventrally, there is a slight enlargement extending for some distance along the joint; from the middle of this projects the tubular process so characteristic of the males of this genus. In this case its length is ·7 mm.

The female is larger, and the conspicuous genital apertures open on the second coxæ of all the legs, and the distal extremities of these joints are much dilated in consequence.

The females appear to be larger than the males.

Eleven specimens of this species were taken in Scotia Bay at a depth of 14 fathoms,

March 1903. One of the males is carrying a large number of young. Some of these, recently hatched, have a very stout, massive body bearing no resemblance to the structure of the adult. The proboscis and chelifori are very distinct; two pairs of small appendages lie behind these. They show a segmentation into joints. Half way between these and the posterior extremity of the body-mass is another pair of appendages, stout stumps with two segments indicated. The majority of the young, however, are much larger. The proboscis and chelifori are well developed; the two following pairs of limbs are quite small, showing few segments and terminating in a long spine or claw. These are obviously the palps and ovigers. Behind these are three pairs of well-developed legs, and the body terminates in a rounded sac. The legs bear a few spinous setæ and more numerous finer ones.

This species is unquestionably a very close relation of *Pallenopsis pilosa*, Hoek. The spurs on the lateral processes and legs serve to separate it pretty sharply. Dr Hoek's species is a deep-water form.

### *Nymphon longicoxa* (Plate I., figs. 3, 3*a*).

*Nymphon longicoxa*, Hoek, (15), pp. 38–39.

*Specific Characters.*—Body and limbs very slender, lateral processes widely separated. Palps five-jointed. Proportion of three terminal joints as 4·5, 2, 3.

Oviger ten-jointed. Denticulate spines numerous, each with three or four lateral teeth.

Legs long, slender, and setose; second coxa much longer than the other two together; no auxiliary claws.

Body very slender, and limbs long; lateral processes very widely separated. Segmentation distinct.

The Cephalon is long, its segment just longer than the proboscis. Just behind its centre it is enlarged to form the ventral support of the ovigers; anteriorly to this it forms a very slender neck, and is comparatively little expanded to form the lobes which support the proboscis, chelifori, and palps.

The Ocular tubercle is very short and stout; it lies just between the first pair of lateral processes and the enlargement that carries the ovigers. It bears four distinct eyes.

The Abdomen is of moderate size, cylindrical, directed upwards, but not articulated to the trunk.

The length of the body is 8·5 mm.; of the trunk only, 7 mm.; and its width is 3·5 mm. It is entirely devoid of setæ.

The Proboscis is long, slender, scarcely as long as the cephalic segment; it is cylindrical, slightly swollen in the middle, and rather abruptly rounded distally.

The Chelifori are long and slender; the scape is single-jointed, longer than and overreaching the proboscis; a few small setæ are distributed along it, and there is a small

distal fringe. The chelæ are much longer than the scape, and the fingers are longer than the palm, which is minutely setose throughout. The dactyli are much curved at the tips, and provided with very numerous slender and close-set teeth.

The Palps arise immediately outside the chelifori. They are long and slender, the second joint not quite reaching to the extremity of the proboscis. As usual, the first joint is very small, and the second is the longest of the appendage, the proportions of the four joints being 7, 4·5, 2, 3. The second joint bears only a very few setæ, and these distally; the third is also scantily setose; the fourth joint is well provided with setæ along its ventral margin, and the terminal one is similarly provided, but these are smaller and extend to the dorsal surface.

The Oviger is ten-jointed, the first three joints being short and stout; the second and third are subequal in length. The fourth is long and rather stout; the fifth is more than half as long again, and quite the longest of the appendage. It is greatly curved, proximally very slender, but gradually becoming much enlarged distally. It bears fine setæ along the inner side of the curve, and a row of spinous papillæ on the opposite side of the enlarged extremity. The sixth joint is curved in the opposite direction, and rather more than one-third the length of the preceding. It is covered with fine setæ on the outer part of the curve. Both these joints are measured across the curve. Of the four terminal joints, the first is longest, the other three being subequal. The terminal one bears a claw nearly as long as itself; this is armed with a dozen slender teeth with fairly wide intervals between them. All the four joints are setose dorsally. The denticulate spines are numerous—15, 9, 8, 9—and consist of a slender tapering and flattened shaft with three rather long lateral teeth on each side, and these only rarely arise opposite to one another. The spines are rather worn, especially on the two distal joints.

The Legs are of great tenuity, and attain a length of about 55 mm. Of the three coxæ, the second is much longer than the other two together, measuring but little less than 5 mm. in length. The proportions of the three following are 10, 12·5, 19. The tarsus and propodus together measure rather more than 4 mm., the latter being the longer joint and carrying a very long slender claw without auxiliaries. The limb is setose throughout, the setæ being arranged for the most part in rows. A lateral line is readily distinguishable. On the first coxæ setæ are rather scanty; on the second they are not plentiful, except ventrally and distally, where they form a fringe; on the third they are fairly uniformly distributed, and a distal fringe is present. On the femur they are sparsely distributed and form a dorsal distal fringe. On the ventral surface of this joint there is a row of very small tubercles. On the tibiæ the setæ become much more numerous and longer, especially towards the distal extremity of the second, where they approximate to those found on the succeeding joints. On the tarsus and propodus they are short and very close set, particularly the ventral row; the dorsal setæ are somewhat more spinous.

The Genital apertures of the male occur on the second coxæ of the three posterior

pairs of legs; those of the female on all the legs. One male is carrying ova; these are large, and few in number.

I cannot find any reasonable ground for regarding this species as distinct from *N. longicoxa*, Hoek. The principal differences seem to be the setose nature of the legs, and the denticulate spines on the ovigers, which in Dr HOEK's specimens bear seven lateral teeth.

Several specimens were taken in lat. 71° 22′ S., long. 16° 34′ W., in 1410 fathoms, 18th March 1904.

### *Nymphon compactum* (Plate I., figs. 5, 5*a*).

*Nymphon compactum*, Hoek, (15), pp. 41–43.

*Specific Characters.*—Body stout, sparsely hairy; eyes obsolete.
Palps five-jointed; proportions of last three, 5, 2·5, 2·5.
Oviger ten-jointed; denticulate spines numerous, with four to six lateral teeth.
Legs long; auxiliary claws absent.

Body stout, with the lateral processes short and not widely though very distinctly separated. The cephalon is short, much widened anteriorly to form two well-marked and divergent lobes for the support of the chelifori. The neck is very distinct, narrowest just behind the cephalic lobes; the space between these and the first pair of lateral processes is completely filled by the body-process from which the ovigers arise. This body-process is conspicuous from the dorsal aspect.

The Ocular tubercle lies immediately in front of the first pair of lateral processes; it is stout, of very small elevation, and bears no trace of eyes.

The Abdomen is pyriform, a little longer than the cephalon; it is not articulated to the trunk.

The segmentation is not at all prominent, the articulations being immediately behind the lateral processes.

The length of the body is 9·5 mm., of the trunk, 7 mm.; and its width is 5 mm.

The Proboscis is directed downwards, cylindrical, and measured ventrally it just exceeds 4 mm.

The Chelifori are well developed. The scape is single-jointed and extends just beyond the end of the proboscis. It bears a number of fine long setæ arranged in an irregular linear manner, and also forming a fairly well-defined distal fringe. The chela is long and narrow, the palm being shorter than the slender fingers; the palm is covered with fine setæ nearly half way along the immovable finger, and there is a fringe of stout setæ at the base of the movable one. The fingers are, as usual, much incurved at the tips, and provided with very numerous, close-set, slender teeth, not very irregular in length. Those of the movable finger are the larger.

The Palps arise close to the chelifori and are of the normal five joints. The first

is very short and stout, the proportions of the remainder being 6, 5, 2·5, 2·5. The second bears a few scattered setæ and a well-marked distal fringe; the third is rather thinly covered with smaller setæ, especially distally. On the ventral margin of the two terminal joints the setæ are stouter than elsewhere and very abundant; dorsally they are rather scanty but much longer. The last joint but one has a well-developed distal fringe dorsally.

The Ovigers are ten-jointed, and arise from stout processes on the ventral surface of the neck. The first three joints are very small, and while progressively increasing in length diminish in diameter. The three together are a little longer than the fourth; the proportions of this and the remaining joints are 8, 10, 7, 3, 2·5, 2, 2·2. The fourth joint is curved and stout; it bears a row of small setæ along the greater part of its outer margin, and a small distal fringe. The fifth joint is slender proximally, but considerably enlarged distally, the transition being gradual and not abrupt; it is covered, but not very thickly, with long slender setæ. The following (sixth) joint has its inner border curved and is thinly covered with setæ finer and shorter than those of the preceding joint. Of the four terminal joints, the first two bear a distal fringe only, and the distal pair bear a few long setæ dorsally in addition. The terminal claw is very nearly as long as the joint that bears it, and carries about eleven teeth. Most of them are long, curved, and have a considerable interval between them. The denticulate spines are numerous—11, 11, 8, 9—and consist of a tapering flattened shaft with four or five well-developed broad teeth on each side; traces of a sixth may sometimes be detected. The second from the base is usually the largest. The spines on the terminal joint are on the whole shorter and broader than elsewhere.

The legs are long, attaining a length of nearly 42 mm. Of the three coxæ, the second is the longest, but scarcely as long as the other two together; the proportions of the remainder being 9, 11, 10, 3·5, 2, and 1 for the terminal claw, which is without auxiliaries. The limb is setose throughout, but not in any conspicuous manner, the setæ being slender and rather long for the most part; they are arranged in four rows, dorsal, ventral, and lateral, and as usual are most conspicuous on the tibiæ; towards the end of the second they tend to become spinous. They are small and numerous on the tarsus, smaller still on the propodus, where the lateral rows are indistinguishable. A lateral line is conspicuous throughout. The distal fringes do not offer any special peculiarities, except that of the third coxa, which is very conspicuous ventrally.

The Genital apertures of the male are on the second coxæ of the two posterior pairs of legs; those of the female are found on all the legs.

The subject of this description is a fine male, which carries two small spherical packets of rather large eggs slung over the proximal part of the fifth joint of each oviger by stout threads.

Three specimens were taken in 1775 fathoms, lat. 62° 10′ 5″ S., long 41° 20′ W.

There can be no doubt that these specimens are identical with *N. compactum*, Hoek.

I have redescribed it on account of small defects in matters of detail in Dr HOEK's original description.

*Nymphon capense* (Plate I., figs. 2, 2*a*).

*Specific Characters.*—Body stout, with lateral processes distinctly but not widely separated. Cephalon with enlarged base.
Palps five-jointed. Four joints progressively decreasing in size.
Ovigers ten-jointed; denticulate spines numerous, each having eight lateral teeth.
Legs slender; claw large, without auxiliaries.

This is a rather small species, with slender limbs. The body is stoutly built, with the lateral processes very distinctly but not widely separated. The segmentation is very distinct, and the body is perfectly smooth and transparent.

The Cephalon is slightly longer than segments two and three together, enlarged at its base, dorsal to the origin of the ovigers, and having a well-developed neck, and is then widely expanded; the cephalic lobes are divided nearly to the base by a distinct groove.

The Ocular tubercle is stout, of little elevation, rounded, and carries four well-developed eyes; it lies in front of the first pair of lateral processes.

The Abdomen is short, not articulated to the trunk, directed upwards, scarcely projecting beyond the last pair of lateral processes.

The length of the body is very nearly 3 mm.; its width is 1·6 mm.

The Proboscis is about 1·6 mm. long, measured ventrally. It is rather bottle-shaped, stout at the base; near the middle it is enlarged; beyond this its diameter is only very slightly reduced; the distal extremity is rounded, and the mouth fairly large.

The Chelifori are well developed. The single-jointed scape is a little longer than the proboscis, and bears a few very small setæ and a small distal fringe. The chela is longer than the scape, and the fingers longer than the palm and much incurved at the tip. The teeth are very closely set, and of three regularly alternating sizes, the space between the longest teeth being occupied by two small ones and an intermediate one between them.

The Palps are five-jointed as usual. The first is very small; the second is the longest, and devoid of setæ; the others progressively decrease in length, the proportions of the four being 5·5, 5, 3·5, 2·8. The third carries a few small setæ, but the fourth is most conspicuously setose and has a prominent distal fringe. The setæ on the terminal joint are short, except distally, and not very abundant.

The Ovigers are ten-jointed, and rise on a conspicuous body-process just in front of the first pair of lateral processes, and very distinct from the dorsum. The first three joints are very small, but progressively increase in size, forming a small but distinct curve; the next three form a slight curve in the opposite direction; these three progressively decrease in length, but not by much, the fourth joint of the appendage

being the longest. All these joints are devoid of setæ, except for a distal fringe on the sixth. Of the four terminal joints, the difference in size is very small; the first is the longest, and the next two progressively decrease in length, the terminal one being as long as the preceding one, and carrying a claw three-quarters of its length. The claw bears about fifteen slender teeth rather closely set. The denticulate spines form a single row, and are rather long, more gently tapering than usual, especially near the apex. They are numerous, the numbers being 15, 12, 11, 12. In uninjured specimens there are eight lateral teeth, of which the four basal ones are prominent, the third being distinctly the largest; the others are small and delicate, but the terminal one is a rather large blade. All these four joints bear small setæ dorsally and a small distal fringe.

The Legs extend to about 17 mm. They are slender, and only bear a few very small setæ arranged in rows; on the ventral surface of the propodus they are most distinct. The lateral line is distinct throughout. Of the three coxæ, the second is as long as the other two together, the proportions of the remaining joints being 7, 8, 10·7, 3, 3. The terminal claw is long and slender, about two-thirds or rather more than the length of the propodus. There are no auxiliaries.

Two males bear eggs. These are large, few in number, and carried in very irregular masses. The oviger is but little modified in the male; the fifth joint is more curved and rather dilated distally.

The Genital apertures of the male are on the second coxæ of the two posterior pairs of legs; of the female, on all the legs.

The body of this species is sufficiently transparent to show some details of its anatomy. The "sieve apparatus" is distinctly seen in the proximal half of the proboscis. The nerve chain is readily seen as a chain of five ganglia connected by a double cord. The ganglia are double and partially fused. The first lies just behind the origin of the ovigers and gives off three nerves on each side, the most posterior of which goes to the oviger. The other two cannot be traced into any of the appendages. The posterior ganglion lies on the line of segmentation of the last segment of the body; all of them give a strong nerve to its appendage.

In the female from one to four ova can be seen on the second and third coxæ and the femora. The alimentary canal is distinct in the trunk, but it is not easy to determine its limit in the legs.

A score of specimens, principally females, and some of them in rather a dilapidated condition, were taken 8 miles north of Dassen Island, Cape Colony, 18th May 1904, in 35 fathoms.

### *Nymphon articulare* (Plate I., figs. 4, 4*a*).

*Specific Characters.*—Body well built, with rather long lateral processes, and these well separated.

Palp five-jointed; proportions of the last three 2·5, 1·5, 1·75.

Oviger ten-jointed; denticulate spines not numerous, with six (?) lateral teeth.
Legs: principal joints subequal, tarsus and propodus subequal, terminal claw with two well-developed auxiliaries.

Body stout, with lateral processes long—the second pair longer than the width of the body, and rather widely separated.

Cephalon not long, constricted to form a well-defined neck, and then expanded to form the stout cephalic lobes.

Ocular tubercle rises between the first pair of lateral processes, abreast of their anterior border. It is tall, tapering, and ends in a blunt point where the four eyes occur.

The segmentation of the trunk is distinct but not very prominent, and the abdomen is not separated by an articulation. This part of the body is rather long and slightly pyriform. It carries a few very small setæ, which also occur as distal fringes of the lateral processes.

The length of body is 3 mm., of the trunk only, 2·25 mm.; its width is 1·8 mm.

The Proboscis is almost cylindrical, with a truncated extremity, and its base is reduced a little in diameter. Measured ventrally, it is 1·4 mm. long.

The Chelifori are well developed. The scape is long, 1·3 mm., sparsely covered with setæ. The chela is strong, the palm being setose; the fingers are scarcely as long, much curved, and beset with numerous closely set teeth of variable length.

The Palp arises at the side of the proboscis, and comprises the normal five joints; the first is very small and stout; the second is the longest, and its proportionate length with the remainder is 4, 2·5, 1·5, 1·75. The second joint is sparsely covered with rather long setæ; on the following joint they are much more numerous, and on the two terminals they are more thickly distributed, and chiefly on the ventral surface.

The Oviger arises ventrally between the first pair of lateral processes. The first three joints are very small, the first two being stout and having a very oblique joint between them; the third has the normal oblique joint; the fourth and fifth are subequal in length, the former being much the stouter, the sixth being a little more than half their length. Very few small setæ are to be found on this part of the appendage; they are, however, rather more numerous on the sixth joint. The four terminal joints are very nearly subequal, setose dorsally, and each has a row of a few denticulate spines, 6, 6, 5, 7. The terminal claw is rather long, with about nine teeth not very closely set These and the denticulate spines are rather worn. The spines are curved forwards, probably due to pressure. There are four well-developed teeth on each side, and probably two more delicate ones.

The Legs attain a length of about 9 mm. Of the three coxæ, the second is the longest, but scarcely as long as the other two together; the proportions of the other joints are 4, 4, 4, 2, 2. The terminal claw is about half the length of the propodus, and has two well-developed auxiliaries. The entire limb is covered with rather fine setæ;

they are not very abundant, and the linear arrangement is not distinct; a distal fringe is conspicuous ventrally on the third coxa, more so dorsally on the femur; on the second tibia it is ventral, and the setæ are distinctly spinous but few in number. Setæ are scarce and very small on the tarsus and propodus, and on these joints it is usual to find a ventral row which is to some extent at least characteristic. In this species this row consists of very inconspicuous setæ, and placed at comparatively large intervals.

Three specimens were found among a large number of *Chætonymphon orcadense*. They are all adult females, and attention was attracted to them by the peculiar enlargement of the femora. These joints are not enlarged throughout, as in most species, but considerably bellied for about two-thirds of their length.

### *Chætonymphon brevicaudatum.*

*Nymphon brevicaudatum*, Miers, (20), pp. 200–214.
*Nymphon horridum*, Böhm, (1), p. 172.
*Nymphon brevicaudatum*, Hoek, (15), pp. 49–52.

Three specimens of this species were taken in Scotia Bay, South Orkneys. They were found amongst an immense number of *Chætonymphon orcadense* captured during the autumn and winter of 1903 inside the 15-fathom line. The specimens are: an adult female, an ovigerous male, and a small one of which the sex is uncertain. All of them show the setæ of the body arranged in the stellate manner described and figured by Dr Hoek; but that author distinctly states that the setæ are not placed in regular rows on the legs. In these specimens this is a striking feature; the setæ are long and coarse, arranged in five rows, two dorsal, two lateral (and these are the longest), and a single ventral row, where they are shortest but most numerous. This arrangement is most noticeable on the tibiæ. Smaller and finer setæ are also irregularly distributed over the appendage, but more particularly on the ventral surface of the coxæ, especially the third, and the femora. The tarsus and propodus are much more slender than the rest of the appendage, the latter being a little the longer, and here the setæ are small and there is a well-developed ventral row; dorsally and laterally the linear arrangement is indistinct. The terminal claw is accompanied by two well-developed auxiliaries.

The ova carried by the male are not very numerous, but large.

### *Chætonymphon mendosum.*

*Chætonymphon mendosum*, Hodgson, (13), pp. 30–32.

*Specific Characters.*—Body robust and tapering; articulation imperfect; lateral processes not widely separated, and with stout spines distally and dorsally; no fine setæ whatever.

Ocular tubercle short and stout.

Palp five-jointed; proportions of last three 5·5, 1·5, 1·6.

Oviger ten-jointed; denticulate spines few, with four teeth on each side, two of them prominent.

Legs with five rows of spinous setæ, without enlarged bases; terminal claw with two small auxiliaries.

I have fully described this species in the Report quoted above. Its occurrence on the opposite side of the Polar area is a matter of great interest. No less than thirteen specimens of both sexes were found among an immense number of *Chætonymphon orcadense* from Scotia Bay, taken in depths of less than 15 fathoms. As in the case of those taken by the *Discovery*, the body is quite smooth, and while there is a fair amount of variation in the setose covering of the appendages, its arrangement is characteristic. The lateral processes carry two stout spines dorsally and distally; but the number is not confined to two. Two other smaller ones may be found outside the principal ones. The spinous armature of the coxæ varies more, and while the setæ on the femur are not so regular in their distribution, the characteristic five rows of strong setæ are conspicuous on the tibiæ, the two dorsal rows having the smaller setæ. One specimen—the largest, and an adult female—has its setose covering the least well developed.

The Ocular tubercle of all these specimens is rather flattened and tapering from a broad base.

The Denticulate spines, which in the type specimens were rather worn, are here well preserved. The large female already alluded to has the same number as the type; the males may have fewer.

The shaft tapers, and may have as many as five lateral teeth, the fifth being little more than a trace.

*Chætonymphon orcadense* (Plate II., figs. 2, 2*a*).

*Specific Characters.*—Body robust, with lateral processes close together, setose.
Palps five-jointed; proportions of three terminal joints 4, 2·5, 2·5.
Oviger ten-jointed; denticulate spines rather numerous, with 5–7 lateral teeth.
Legs coarsely setose, with terminal claw and well-developed auxiliaries.

Body robust, with lateral processes of unequal length, giving it an ovoid form; they are distinctly though not widely separated, variable, apparently depending on age. Segmentation is very distinct.

The Cephalon is not long, constricted near the middle to form a distinct neck, and then widely expanded, forming two prominent divergent lobes. In length it is about two-thirds of the first trunk segment.

The Ocular tubercle is rather stout, not quite clear of the first pair of lateral processes. It is tall, rounded at the extremity, where there are four well-developed eyes.

The Abdomen is not articulated to the trunk, very distinctly pyriform in shape, and not quite so long as the cephalon.

The entire animal is covered with setæ; on the body they are quite small. The length of the body is 8 mm., its width 5·5 mm.

The Proboscis is not half the length of the body, cylindrical, with a constricted base, and truncate at the extremity. It is finely setose throughout.

The Chelifori are strongly developed. The scape is a single joint longer than the proboscis, richly supplied with setæ, which are most conspicuous on the inner side, some of the dorsal ones being very powerful; the distal fringe is strongly developed, the setæ being of varied size. The chelæ are as long as the scape, the palm fairly stout and covered completely with short setæ, which extend well on to the immovable finger. The two fingers are slender, much curved at the tips, and furnished with a large number of closely set teeth, which are fairly regular in size.

The Palps are five-jointed, and rise below the chelifori, at the side of the proboscis. The first joint is very small; the second is the longest; the proportion of that to the remainder is 5, 4, 2·5, 2·5. The entire limb is setose, setæ being fairly plentiful on the second joint and becoming more numerous to the distal extremity of the appendage. They are thickest on the ventral surface of the two terminal joints; the third and fourth have well-developed distal fringes.

The Oviger is ten-jointed, and rises ventro-laterally just in front of the first pair of lateral processes. The first three joints are very small and stout, the second and third being subequal, the latter having, as usual, a very oblique termination; the fourth is slightly curved, about as long as the first three together, and stouter distally than proximally; the fifth is fully half as long again, more strongly curved, enlarged distally, and having a curious constriction about a quarter of its length; the sixth is about one-third the length of the fifth, and has a well-developed setose tubercle at its extremity; the seventh joint is articulated at the outer angle of the sixth, but this is not always easy to observe. The four terminal joints differ but little in size; the first three progressively decrease in length, and the fourth is as long as the second. The terminal claw carries upwards of a dozen slender teeth. The denticulate spines are in a single row of 12, 8, 7, 10 on the four joints. Each spine is a stout blade with from five to seven lateral teeth; the middle ones are the largest, and the distal ones only exist as a mere trace. The entire appendage is setose; the setæ are small; the fourth joint carries them on the outer side of its curve, the fifth also, but distally they are much more evenly distributed; the sixth is completely covered, and the four terminal joints are provided dorsally with numerous setæ, longer than elsewhere. The oviger of the female presents considerable differences from the above. The limb is much more slender; the fourth and fifth joints are large, slightly curved, stoutest distally, and subequal in length. The setose tubercle at the extremity of the sixth joint is not noticeable. The number of denticulate spines on the various joints is not quite constant, nor are the teeth on the terminal claw. The setose covering is not so well developed.

The Legs attain a length of 32 mm. Of the three coxæ, the second is about as long

as the other two together; all are fairly uniformly covered with short setæ; the distal fringe of the third is, however, ventral and composed of numerous long slender setæ, and these are most conspicuously developed on the two posterior pairs of legs of the male —obviously a sexual character. The three following joints differ but little, their proportions being 6·5, 7, 7·25; the tarsus and propodus being as 3 to 2·5. The terminal claw is rather slender, and is accompanied by two auxiliaries less than half its size. The limb is thickly covered with setæ of no great size, but variable in length; they are longer and stronger laterally than elsewhere. This is not so conspicuous on the femur as on the tibiæ; they are largest on the second tibia, though the general covering of this joint is much finer than on the preceding joints. On the tarsus and propodus the setæ are small, uniform in size, and thickly set. The distal fringe of the femur is dorsal and composed of long stiff setæ; that of the first tibia is ventral and rather more spinous; that of the second tibia is also ventral and composed of strong spines.

The Genital apertures of the male are only to be found on the second coxæ of the two posterior pairs of legs; those of the female occur on every leg.

Of the enormous number of specimens taken in Scotia Bay, but a few males carry eggs. These are rather large, 0·7 mm., and between thirty and forty in a packet. This is slung over the fifth joint of the oviger by a stout thread near its proximal end. Another specimen carries a very large mass of young. These show the chelæ well developed, as are also the first two pairs of legs; the third pair are conspicuous rudiments, and the fourth pair can be seen as a swelling on either side of the abdomen. Rudiments of the palps are visible, and the ocular tubercle is present. Scotia Bay, about 10 fathoms. Burdwood Bank, south of the Falkland Islands, one specimen, immature, 56 fathoms.

### *Chætonymphon assimile* (Plate I., figs. 1, 1*a*).

*Specific Characters.*—Body robust, with lateral processes very distinctly separated; devoid of setæ but for the distal fringes.
Palps five-jointed; proportions of last three 7·3, 4, 4.
Ovigers ten-jointed; denticulate spines not numerous, with five (?) lateral teeth.
Legs with long terminal claw and very minute auxiliaries.

The Body is stoutly built, with the lateral processes distinctly but not widely separated, and they carry a few stout setæ as a distal fringe; otherwise the body is quite smooth. Segmentation is distinct but not prominent, and the abdomen, which is pyriform and directed upwards to clear the posterior lateral processes, is not articulated to the trunk; it only bears two small setæ near its extremity, sometimes more.

The Cephalon is short, constricted to form a distinct neck, and then expanded to form two divergent lobes.

The Ocular tubercle lies between the neck and the first pair of lateral processes as a tall cylindrical structure, having at its rounded summit four well-developed eyes.

The length of the body is very nearly 6 mm., and its width 3 mm.; the abdomen takes up 1·2 mm.

The Proboscis is cylindrical, and is thinly covered with small setæ; the extremity is truncated.

The Chelifori are strongly developed. The scape is single-jointed and 2·3 mm. long; it is covered with small setæ and a row of three or four spinous ones along the mid-dorsal surface, and a distal fringe of the same kind. The chelæ are about as long as the scape, the dactyli being longer than the palm, which is covered with very short setæ well on to the base of the immovable finger. Both fingers are much curved at the tips and bent on their inner margins, with numerous closely-set, slender teeth not of uniform size.

The Palps arise at the side of the proboscis, and comprise the normal five joints. The first is small and stout; the second is the longest, but only by a very little, the proportions between it and the remaining joints being 8, 7·3, 4, 4. The second joint bears a few setæ scattered along it, and two or three distinctly spinous ones, and a distal fringe of stout setæ. The third joint is more plentifully supplied with setæ, more uniformly distributed; the distal fringe is well developed ventrally. The two following joints are still more richly supplied on the ventral surface, but not to the same extent dorsally.

The Ovigers arise in the angle between the first lateral process and the cephalon, the body-process being distinctly visible dorsally. Of the ten joints, the first two are very small and stout; the third is as long as the two together. The fourth and fifth are almost subequal, the fifth being a very little the longer; the former is stout, the latter more slender and covered on its outer margin with short stiff setæ; the sixth is comparatively long, just exceeding two-thirds the length of the fifth, and is similarly setose. The four terminal joints differ but little in size; the third is perhaps the smallest; the dorsal surface of all is well provided with rather long setæ, and the terminal claw carries about a dozen teeth. The denticulate spines are not numerous (9, 8, 6, 9). They are much worn, as are also the teeth on the terminal claw, but exhibit a tapering shaft with three strongly developed lateral teeth and probably two more delicate ones.

The Legs attain a length of 20 mm. Of the three coxæ, the second is not so long as the other two together; the proportions of the remaining joints are as 8, 11, 10, 4·5, 3. The terminal claw is long and slender, and the auxiliaries are extremely minute. The entire limb is setose. The setæ on the coxæ are scanty dorsally, being limited to a poorly developed fringe on the first, and a lateral row on the second; but the ventral surface of the second and more particularly the third are covered with short stiff setæ and distinct distal fringes. The femur is irregularly clothed with rather long setæ dorsally, and a prominent distal fringe; ventrally the setæ are quite small. A similar arrangement holds good on the two tibiæ, but there is in addition a lateral row of stout spinous setæ situated at rather long intervals. The distal fringe of the first tibia is inconspicuous but for one stout spine ventro-laterally, and on the second tibia it is

composed ventrally of stout spines. On the tarsus and propodus the setæ are small and inconspicuous; there is a row ventrally along the two joints in which the setæ are more regular than elsewhere, but there is nothing very distinctive about them.

The specimen described above is an adult female, and the genital apertures occur, as usual, on all the legs. Those of the male occur only on the two posterior pairs of legs. The male differs further in being more coarsely setose, though the arrangement of the setæ is identical. The fifth joint of the oviger is abruptly expanded to more than twice its normal diameter, and the sixth joint is also expanded considerably, but is reduced to something like normal diameter distally. The denticulate spines are a little more numerous than in the female, being 11, 7, 6, 8.

A number of specimens were taken in Scotia Bay, in less than 10 fathoms, during the stay of the *Scotia*.

### *Pentanymphon antarcticum.*

*Pentanymphon antarcticum*, Hodgson, (10), pp. 458–462; (11), p. 35; (13), pp. 36–39.
„ „ Cole, (6), p. 105; Bouvier, (3), p. 4.

Only a single specimen, an adult female, was taken by the expedition, and was found among a large number of *Chætonymphon orcadense* from Scotia Bay, in 10 fathoms. It is more robust than the average specimens from M'Murdo Sound; the scabrous nature of the body is more distinct, but this is not readily noticeable. Its neck, though a little shorter in proportion to the type specimens, does not appear to be more than an individual peculiarity. The joints of the legs have the same proportions as the types, but the tarsus and propodus vary on the different limbs more than usual for a single individual. The denticulate spines of the ovigers are much worn, and quite useless for specific discrimination. The genital apertures occur on the second coxa of all the legs.

Scotia Bay, 10 fathoms.

### *Ammothea communis* (Plate II., figs. 1, 1*a*).

*Ammothea communis*, Bouvier, (3), p. 6.

*Specific Characters.*—Body discoid, with lateral processes close together; they and the first coxæ armed dorsally with two stout spurs.
Palps eight-jointed, last three progressively increasing in length.
Oviger ten-jointed, small; few denticulate spines, no claw.
Legs stout, uniformly setose; terminal claw stout, with two well-developed auxiliaries. Four strong spines on propodus.

Body discoid, the lateral processes being close together; these are armed with two stout spurs dorsally and distally, and similar but stouter ones occur on the first coxæ. Of these the posterior one is always the largest.

The Cephalon is stout, and also provided anteriorly with a short but stout spur on each side, and between these is the stout Ocular tubercle. This is short, blunt, and rounded, but bears a small pointed tubercle at the apex. Of the four well-developed eyes, the anterior pair are the larger.

The Abdomen is rather long and cylindrical, directed upwards, but not so much so as in Professor BOUVIER's specimens. Very small setæ occur on the abdomen and all the spurs of the cephalon and lateral processes.

The length of the body is 1·7 mm., and its breadth 1·3.

The Proboscis is large, pyriform, rather more than half the length of the body.

The Chelifori are as is usual with the members of this genus; the scape is short, slightly curved, with but few minute setæ, and those distally. The chela is reduced to a mere knob, with but traces of the dactyli.

The Palps are eight-jointed and rise laterally to the proboscis. The first joint is short and stout; the second and fourth are subequal and about three times as long, the latter bearing a few setæ ventrally. The third joint is quite small, with two or three setæ dorsally. The four terminal joints are all small, and differ but little in size; however, the last three progressively increase in length, the terminal one being distinctly the longest and rather irregular in shape; it is richly supplied with short stiff setæ ventrally and distally, to a less extent dorsally. The other joints are enlarged a little ventrally, and carry a tuft of short stiff setæ.

The Oviger is ten-jointed, short, with all the joints small. The first is short and stout; the second is much longer and more slender; the third, shorter than the preceding one; the fourth and fifth are subequal, slightly curved, and the longest of the appendage, the proportions of the third to these being 3, 4, 4. The sixth is small, the seventh a little longer and more slender; the remainder graduate to a very small terminal joint. Very few setæ are to be found on the entire appendage, and the denticulate spines are also in very small numbers (1, 2, 1, 2). They consist of a slightly curved shaft with the flattened blade cut into nine very closely set teeth. On the sixth joint there are two spines, and another on the seventh, which look as if they were much-worn specimens of the denticulate spines. This would increase the formula to 2, 2, 2, 1, 2.

The Legs attain a length of 6 mm. The first coxa is stout, with two dorsal spines, as before stated; the second is longer, slender, but enlarged distally, not as long as the other two together. The proportions of the three following joints are as 6, 6, 5. The tarsus is very short; the propodus is curved and bears a stout terminal claw and two very well-developed auxiliaries. The entire limb is covered with short and rather stiff setæ. The tarsus sometimes bears a stout spine ventrally. The propodus has four stout spines ventrally and proximally, the remainder of the ventral surface being occupied by a band of stout setæ. The difference between these and the four proximal spines is not so sharply marked as in some species. The femora bear a stout tubercle dorsally and distally.

The Genital apertures are on a prominent outgrowth at the distal extremity of the second coxæ of the two posterior pairs of legs. The eggs are numerous, and two roughly spherical packets may be found on each oviger.

Two specimens, both ovigerous males, were taken in Scotia Bay, at a depth of 10 fathoms.

### *Leionymphon grande.*

*Ammothea grandis*, Pfeffer, (24), pp. 43–45.
*Colossendeis* (?) *Charcoti*, Bouvier, (2), pp. 295–296.
*Leionymphon grande*, Hodgson, (13), pp. 41–43.

This species was first described by Dr PFEFFER as coming from South Georgia. Professor BOUVIER has recorded it more recently from Carthage Bay, where it was taken by the French Antarctic Expedition. A single adult female and several immature specimens were captured by the *Discovery* off Coulman Island in the Ross Sea. In the Report on the *Discovery* Pycnogonida I have described the species at some length, and transferred it to a genus founded by Professor MÖBIUS (22) for an immature species taken off Bouvet Island.

A single specimen only was taken by the Scotch Expedition in Scotia Bay, South Orkneys, 14 fathoms, 26th March 1903. It is a male, not quite adult, retaining the chelate condition of the chelifori; and the genital apertures are not yet developed. In point of size it is a good deal smaller than the adults, but otherwise does not exhibit any important differences. The length of the body is 11 mm., its width 9·5 mm. The proboscis, which tapers very slightly towards the extremity, is 12 mm. long. The legs have a length of only 42 mm., the proportions of the three principal joints being 9·5, 9, 12. There are only three stout spines proximally on the ventral side of the propodus, and the distribution of the short stiff setæ over the legs is quite uniform. The ocular tubercle ends in a cone above the eyes.

These are the only differences to be found between this specimen and the adult taken by the *Discovery*.

The oviger, however, presents important sexual features, and though this specimen is not mature the appendage may be described in detail. The first joint is very small; the second is longer and stout; the third is more slender, and has, as usual, a very oblique termination; if measured to the extremity of this it is about as long as the preceding. Their outer margins are rather thickly covered with short setæ. The three following joints form a curvature in the opposite direction to the first three. Their proportions are about as 5, 6, 3·5, and they are covered with short setæ, but more particularly so on the outer side. The precise proportions of the remaining joints cannot be given, owing to their relations one to the other. The seventh joint is shorter than the preceding, and articulated to it at something like a right angle. Near its distal extremity it bears a tuft of setæ. The eighth joint is richly setose, and also articulated to the seventh at a considerable angle; the two terminals

taper to a blunt point, are devoid of setæ, and do not appear to have attained their full development.

### *Leionymphon Clausi* (Plate II., figs. 1, 1*a*).

*Ammothea Clausii*, Pffeffer, (24), pp. 43–44.
*Leionymphon Clausi*, Hodgson, (13), p. 40.

*Specific Characters.*—Body with lateral processes not widely separated but divergent. Abdomen tall, erect, immediately behind posterior trunk segment.
Palps nine-jointed, the last five differing but little in size.
Ovigers ten-jointed, without terminal claw, and differing in the two sexes.
Legs with strong terminal claw and auxiliaries; about five stout spines ventrally and proximally on the propodus.

The Body is robust, with the lateral processes rather long, distinctly but not widely separated, divergent. Segmentation rendered conspicuous by three prominent transverse ridges, which are rounded and not produced into a median point.

The Cephalon is but very little expanded. Its anterior margin is straight, and it is about two-thirds the length of the anterior segment. At its antero-lateral angle it bears a distinct tubercle, and there are two more similar ones on each side of the lateral processes. Here the posterior one of each pair is the largest.

The Ocular tubercle lies slightly in advance of the middle line of the cephalon; it is tall and cylindrical, bearing four well-developed eyes, above which it terminates in an elongated cone.

The Abdomen is directed straight upwards, and lies so close to the posterior segment that the line passes over its base. It is cylindrical, tapering distally to a blunt point. The length of the body, measured to the extremity of the posterior lateral processes, is barely 6 mm.; its width is 4 mm.

The Proboscis is pyriform, quite smooth, and fully 5 mm. in length. Movably articulated to the body, it is carried directly downwards at a considerable angle.

The Chelifori are rudimentary; they arise from the anterior margin of the cephalon above the proboscis, and are curved, having a few setæ distally. The chelæ are irregularly shaped knobs inclined downwards, with small tubercles to represent the dactyli.

The Palps arise just below the chelifori at the sides of the proboscis, and are nine-jointed. The first joint is short and stout; the proportions of the three following are as 6, 1, 4·5; the remaining five differ but little in size, and, retaining the proper numbers of each joint, their sequence in point of length is as follows: 5, 7, 9, 6, 8. The entire appendage is covered with very small setæ, and these are specially numerous on the ventral surface of the five terminal joints.

The Ovigers are ten-jointed and arise ventro-laterally from a small body-process on the neck, and therefore immediately in front of the first pair of lateral processes.

Between the two sexes they exhibit considerable differences. The type specimens are males, and the specimen now under examination is an adult female.

All the joints are small; the first is short and stout; the second, fourth, and fifth are subequal, and, by a little, the longest joints of the appendage; the third is about two-thirds the size of these; the sixth is a little shorter than the preceding; the seventh and eighth are a little shorter still and subequal; the ninth is the shortest of all, except the first; and the tenth is slender, rather tapering, and half as long again as the ninth. Setæ are very scarce throughout, except on the sixth joint, where they are fairly numerous though minute. The last four joints bear numerous denticulate spines, which are not, however, arranged in a single row. These are unfortunately much worn, but show a stout, usually curved shaft, bent, with some eight or nine very closely set teeth on each side. There is no terminal claw.

The Legs extend to a length of about 27 mm. Of the three coxæ, the first is the shortest, the second is rather more than twice as long, and the third is intermediate between the two. The proportions of the three following joints are as 6, 5, 7, but they are not strictly preserved on all the legs. The tarsus is very small, covered with stiff setæ, which become distinctly spinous as a ventral distal fringe. The propodus is rather curved; ventrally and proximally there is a row of very stout spines, five in number. The rest of the joint is thickly covered with short stiff setæ, especially ventrally; dorsally there are a few longer ones. The heel does not project much and is fringed with stiff setæ. The terminal claw is long and stout, with two large auxiliaries more than half as long; the three rise from a common membranous investment.

The limb is covered fairly plentifully with short stiff setæ, and there are rows on the principal joints of stout spinous setæ dorsally and laterally; these are, however, not closely set. The distal fringes are not conspicuous.

The Genital apertures are found on the second coxæ of all the legs.

A single specimen was found among an enormous number of *Chætonymphon orcadense* taken in Scotia Bay, at 9 fathoms.

Through the courtesy of Dr Pfeffer of Hamburg, I have been able to compare this specimen with the types of his *Ammothea Clausi*. Though Dr Pfeffer's specimens are both ovigerous males, there cannot be any question as to the identity of this specimen with that species. The ova are small and numerous, massed together in two spherical packets on each oviger.

### *Decolopoda australis* (Plate III., figs. 2, 2*a*, 2*b*, 2*c*).

*Decolopoda australis*, Eights, (8), pp. 203–206; Stebbing, (29), pp. 185–189; Cole, (6), pp. 405–415; Loman, (19), p. 722.

*Decalopoda australis*, Hodgson, (11), pp. 36–42; (12), pp. 254–256; Bouvier, (3), pp. 1–5.

This fine species was discovered in some numbers along the shores of the South Shetland Islands, and a very full description was published by Dr Eights in the first

volume of the *Boston Journal of Natural History* in 1837. The description is clear and accurate; if the plate which accompanies the paper is not as good as it might be, it is readily recognisable, and quite as good as many produced at the present day. It is more than probable that the title of the paper has contributed largely to its having been overlooked for so long; but that does not justify the reception allotted to it when discovered. It would appear that a Pycnogonid with five pairs of legs was not to be tolerated, and two well-known zoologists have failed to recognise such a possibility. However, the species has been rediscovered, and another totally distinct and not closely related species, also with five pairs of legs, has been discovered in the distant south. The modern discovery which has led to a proper appreciation of EIGHTS' species has been achieved by the recent Antarctic expeditions, three of which secured a number of EIGHTS' species from the South Orkneys, in latitude 61° S. The discovery of such an interesting form was deemed of sufficient importance to warrant its prompt publication, and it was not till that was undertaken that the significance of EIGHTS' work came to light. In a communication made to the Royal Physical Society of Edinburgh (11), EIGHTS' original description has been republished verbatim, together with a more modern one. It is a matter of opinion which is the better of the two; the plates, however, are much superior, and give a very accurate idea of the animal.

The more recent description is republished here, with some verbal alterations, and some further information is added in a final paragraph.

*Decolopoda australis*, EIGHTS.

*Specific Characters.*—Body stout, discoid, with only occasional traces of segmentation, with a group of three or four very small spines on the dorsal surface of the lateral processes, which are quite close together.

Proboscis large, bent downwards just beyond the middle of its length, with minute spines dorsally.

Palps: third joint considerably the longest; the three terminal joints subequal, and shorter than the seventh.

Legs smooth; setæ restricted to spinous distal fringes.

In comparing the South Orkney specimens with EIGHTS' description, one is struck by the accuracy of that naturalist; but according to modern requirements some small points have been overlooked.

EIGHTS describes his specimens as being a bright scarlet, and the body and coxæ of the figure have been so coloured. The South Orkney specimens, after being in spirit for more than a year, do not show any trace of such a colour. Some of the specimens are of a very light straw colour, without any trace of pigment, except in one or two cases where a little is distributed at the extremity of the proboscis. Other specimens are of a rich olive-brown colour, which is considerably darker, almost black, on the proboscis, mandibles, and palps. In one specimen the legs are equally darkly pigmented. The

colour notes taken at the time, and which have been forwarded to me, show that some of the specimens were bright scarlet, as EIGHTS described them; others are a very dark red, and in the latter case the proboscis is almost black. The scarlet colour appears to be uniformly distributed over the body and limbs, the proboscis and adjacent parts being darker than the rest. One specimen shows a distinct segmentation, two others show it very indistinctly, and the remainder not at all.

The Cephalon is short; a distinct neck separates it from the rest of the trunk. It is expanded to completely fill the interval between the first pair of lateral processes.

The Ocular tubercle lies in the middle of the cephalon, and is short and stout; it bears four well-developed eyes below the terminal cone.

The Proboscis is not so long as the body, but longer than the trunk. It is much swollen just beyond the middle, where it bends downwards at a considerable angle. The mouth is small. Along the middle line of the proboscis is a narrow band of small spines, which can hardly be said to have a regular arrangement. More laterally are two or three rows of spines, not always well defined; the inner one comprises several spines, but the outer one only a very few. On the whole, the lateral spines are larger than those of the median band. One or two spines may occur ventrally just behind the bend.

The Chelifori are well developed and the scape is two-jointed. They arise from the wide extremity of the cephalon laterally to the proboscis. The first joint is long, reaching almost to the beginning of the median enlargement of that organ. The second joint is very small, and constitutes the angle in the direction of the appendage; seen laterally, it is practically triangular in shape, the apex downwards and its dorsal margin sinuous. The chela is articulated to the ventral angle, and lies close underneath the first joint. The palm is very small; both fingers are slender and much curved, like a pair of callipers; the tips overlap, and there is no trace of teeth. There are no setæ on the appendage.

The ten-jointed Palps rise ventrally close against the proboscis. It is open to question if the first is a true joint or merely a body-process; it is, however, constricted at the base. The first two joints are very short and wide—annular, in fact; the third is the longest in the appendage, and in proportion to the three following is as 6, 1, 4, 2. The following joints are all small and differ but little in length. The seventh is perhaps the longest, the eighth the shortest; the two terminals are subequal and longer, but the difference is scarcely noticeable. The fifth joint is the stoutest of them all, and slightly constricted about two-thirds of its length. In none of the specimens are the palps setaceous, and this is the only discrepancy between EIGHTS' description and the South Orkney examples.

The Ovigers rise from a body-process immediately behind the palps, close to the middle line of the ventral surface. This body-process is quite as large ventrally as any of the first three joints, which are small, and might easily be mistaken for one. The proportions of the three following joints are as 9·5, 5, 10. The four terminal joints

are subequal in length, and bent on each other to form a loop which is so characteristic of the genus *Colossendeis*. Each joint is furnished with four rows of non-denticulate spines, though on the terminal joint these spines are less regularly arranged, and a fifth row may be distinguished. The spines vary a good deal in form and size; the larger ones are trenchant blades, bent rather close against the surface from which they spring. The terminal claw is long and slender. These spines, as well as the terminal claw, are much worn in all the specimens available, though of course to a varying extent, and I would not assert that I had seen a perfect specimen. It does not appear to me improbable that they should prove to terminate in a flattened blade with a denticulate margin.

The Leg extends to a length of about 83 mm. They differ in length, but without measurement the difference is hardly noticeable. The fifth leg is the smallest, the first comes next, and the fourth is intermediate between the third and fifth; the second and third are the largest and subequal. Of the three coxæ, which are short, the first is the shortest, and the second the longest, the differences being small. The first is marked dorsally and ventrally by a faint groove passing along the greater part of the joint, and rendered more conspicuous by a change of colour. Its distal extremity is marked by a minute spine. The other coxæ exhibit distinctly the "lateral line," which is continued to the extremity of the limb. The proportions of the other joints and claw are as 18, 19, 20·5, 8·5, 7, 5·5. There is a certain amount of variation, but it is confined to narrow limits. Except for the spinous distal fringes, the limbs are perfectly smooth. The distal fringe of the femur consists of one mid-dorsal spine and two lateral; these are quite small and inconspicuous; that of the first tibia is generally deficient; those of the second tibia and tarsus comprise four long spines, each pair being situated ventro-laterally; a mid-ventral spine occurs occasionally. A pair of long spines occurs ventrally on the propodus, one on each side of the claw.

The Genital apertures occur on the second coxa of all the legs; those of the male are small and distal, those of the female are larger and median.

Several specimens of this fine species were taken on various dates in Scotia Bay, South Orkneys, in 9 or 10 fathoms. Two are quite immature, but show no traces of segmentation, and in all particulars, except the non-development of the genital apertures, resemble the mature specimens. Two specimens in the collection were marked as bearing ova, but examination shows that these "ova" were bunches of contracted hydroid polyps, and were held by the mandibles, but close against the ovigers.

*Colossendeis orcadense* (Plate II., fig. 3).

*Specific Characters.*—Body well built, with lateral processes widely separated.

Proboscis considerably longer than the trunk, and enlarged from near the middle onwards.

Palps ten-jointed; proportions of last three joints 1·8, 2·5, 2·5.

Ovigers ten-jointed, the last four joints with five rows of denticulate spines.

Ocular tubercle stout, conical, without eyes.
Legs slender, covered with rows of very minute setæ; terminal claw long.

The Body is fairly robust, without any trace of segmentation, and the lateral processes are widely separated. The cephalon is small, and at its posterior border, not quite clear of the first pair of lateral processes, lies the ocular tubercle. This is a very short but stout and pointed process, without any trace of eyes. The abdomen is slender and articulated to the trunk.

The Proboscis is considerably longer than the body, and is bottle-shaped—that is, it is narrow at the base and for about a third of its length, when it becomes considerably enlarged. At about its distal third it again becomes slightly constricted, and terminates in three lobes corresponding to the sides of the mouth. It is irregularly covered with minute setæ, and movably articulated to the trunk.

The length of the proboscis is 20 mm.; trunk, 13 mm.; abdomen, 2 mm.; width of trunk, 7 mm.

The Palps arise ventro-laterally at the extreme end of the trunk. The first joint, though small, is unusually large, and twice the size of the second, which is annular. The proportions of the other joints are 11, 1·3, 7, 4, 5·75, 1·8, 2·5, 2·5.

With the exception of the first two joints, the entire appendage is setose throughout. On the third joint they are scarce and hardly noticeable, but become more numerous on succeeding joints. From the sixth they are most abundant, always small, and thickest on the ventral aspect of the appendage. On the fifth joint, at about three-quarters of its length, there is a distinct swelling externally and a faint constriction, a peculiarity which seems to prevail throughout the genus.

The Ovigers lie immediately behind the palps, and the processes on which they arise are quite close to the middle line and seem to have pushed the palps off the body. Each might quite justifiably be taken for an eleventh joint; the first three, properly so called, are quite small and approximately subequal. The proportions of the next three are 17, 7·5, 15·2. The four terminal joints present no exceptional peculiarities in general appearance, but the denticulate spines are arranged in five rows altogether—a single row of large spines separated by an interval from a second which contains nearly double the number of smaller spines, another interval, and then three more rows not so regular as the other two. In the ninth joint these latter rows are very irregular. The spines themselves are of the characteristic type—a more or less cylindrical base bearing a flattened blade, the two being subequal in length. In the present specimen they are so much worn that no details as to their margins can be observed.

The Legs are slender and are 110 mm. in length. The three coxæ are small and subequal, the first being very closely articulated to its lateral process, the proportions of the remaining joints being 32, 27, 22, 11, 7, and the terminal claw about 5. The limb is rather liberally covered with very minute setæ, which are arranged in rows. The lateral line is distinguishable throughout. The left femur of the first pair of legs and the

right femur of the last pair bear peculiar excrescences, obviously the result of some injury. In both cases, however, the injured joint is longer than its fellow on the opposite side.

A single specimen, which carries a few individuals of *Scalpellum*, was taken at the South Orkneys in June 1903.

### *Colossendeis leptorhynchus.*

*Colossendeis leptorhynchus*, Hoek, (15), pp. 64–65.

A specimen referable to this species was taken in lat. 48° 6′ S., long. 10° 5′ W., in 1742 fathoms. It differs slightly from the type specimens taken by H.M.S. *Challenger*, and is much larger than any from that expedition. With its legs straightened out it covers an area of very nearly 14 inches. Its length is as follows:—Proboscis, 39·5 mm.; trunk, 13·5 mm.; abdomen, 5 mm.; total, 58 mm.

The Body is perfectly smooth, but traces of segmentation may be seen under a good lens. It is not stoutly built, and the small lateral processes are separated by an interval equal to about half their thickness.

The Cephalon is marked off from the rest of the trunk by a V-shaped groove which cuts into the space between the first pair of lateral processes. The ocular tubercle is immediately in front of this groove, and occupies rather a large area; it is of very small elevation and bears two poorly developed eyes.

The Proboscis is very long and slender, slightly enlarged in the middle, exactly as described by Dr Hoek; but it is movably articulated to the trunk as in the type and all other species of the genus that I have seen, twenty-three in number.

The Palps arise ventro-laterally as close as possible to the proboscis, beyond which they do not extend far, the sixth joint not reaching the extremity. The first two joints are very small, the proportions of the remainder being 14, 2, 20, 2·5, 2·3. The three terminals are together not as long as the preceding joint; the first two are subequal, and the last a little longer, but not as long as the two together. The entire organ is very finely setose throughout.

The Ovigers rise ventrally close together, each on a small body-process which is close behind the proboscis. They are very long; the first three joints are as usual very small, the middle one of these being much more slender than the other two. The proportions of the three following are as 23, 4, 26. The four terminal joints are small and form the characteristic loop, and are provided with groups of denticulate spines, the last joint bearing a strong claw. A lateral line is readily seen along the entire appendage. There are not less than seven rows of these denticulate spines; those of the first and principal row are the longest and best suited for observation. Here they are less numerous than in the other rows. They are roughly cylindrical shafts, becoming, at about half their length, flattened ovoid blades. The margin of the flattened blade is, near the base, provided with very small and rather curved teeth. These become longer and closer set, and before the extremity of the blade is reached they

have become fine setæ. I believe that this appearance is entirely due to wear and tear; these spines and the terminal claw are more or less worn, some of course very much more than others. If in really good condition, I believe these spines would be finely dentate all round the blade.

The Legs are long, very slender, and attain a length of 180 mm. The three coxæ are small and subequal; the proportions of the remaining joints are as 54, 61, 44, 8, 4. The terminal claw is very small. The limb is supplied at long intervals with very minute setæ; these make their appearance on the femur. The relative sizes of the joints of the leg differ from Dr HOEK's specimens, in which the femur is the longest joint. There can, however, be no doubt as to the identity of this species.

In the preparation of this report I am greatly indebted to the Council of the Marine Biological Association of the United Kingdom, and especially to Dr E. J. ALLEN, the Director, for accommodation at their Plymouth Laboratory; also to my friends Mr and Mrs L. E. SEXTON and Mr J. RITCHIE, who have so generously assisted me with the drawings and the photographs from which they have been prepared.

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## EXPLANATION OF PLATES.

### Plate I.

Fig. 1. *Chætonymphon assimile* . oviger × 15.
„ 1*a*. „ „ . ♀ palp × 16.
„ 2. *Nymphon capense* . . palp × 20.
„ 2*a*. „ „ . . oviger × 20.
„ 3. *Nymphon longicoxa* . . oviger × 9.
Fig. 3*a*. *Nymphon longicoxa* . . ♂ palp × 10.
„ 4. *Nymphon articulare* . . ♀ palp × 50.
„ 4*a*. „ „ . . oviger × 28.
„ 5. *Nymphon compactum* . oviger × 8.
„ 5*a*. „ „ . ♂ palp × 15.

### Plate II.

Fig. 1. *Ammothea communis* . . ♂ palp × 35.
„ 1*a*. „ „ . . oviger × 40.
„ 2. *Chætonymphon orcadense* . ♂ palp × 13.
„ 2*a*. „ „ . oviger × 12.
Fig. 3. *Colossendeis orcadense* . nat. size.
„ 4. *Pallenopsis lanata* . . oviger × 14.
„ 4*a* „ „ . . ♂ palp × 16.

### Plate III.

Fig. 1. *Leionymphon Clausi* . × 2.
„ 1*a*. „ „ . ♀ oviger × 8.
„ 2. *Decalopoda australis* . ♂ nat. size.
Fig 2*a*. *Delcalopoda australis* . proboscis from right side × 4.
„ 2*b*. „ „ . oviger, terminal joints × 6.
„ 2*c*. „ „ . cheliferus × 6.

HODGSON: PYCONOGONIDS.—PLATE I.

1.

2.

3.

4.

4,*a*.

5,*a*.

1,*a*.

5.

3,*a*.

2,*a*.

James Ritchie, del

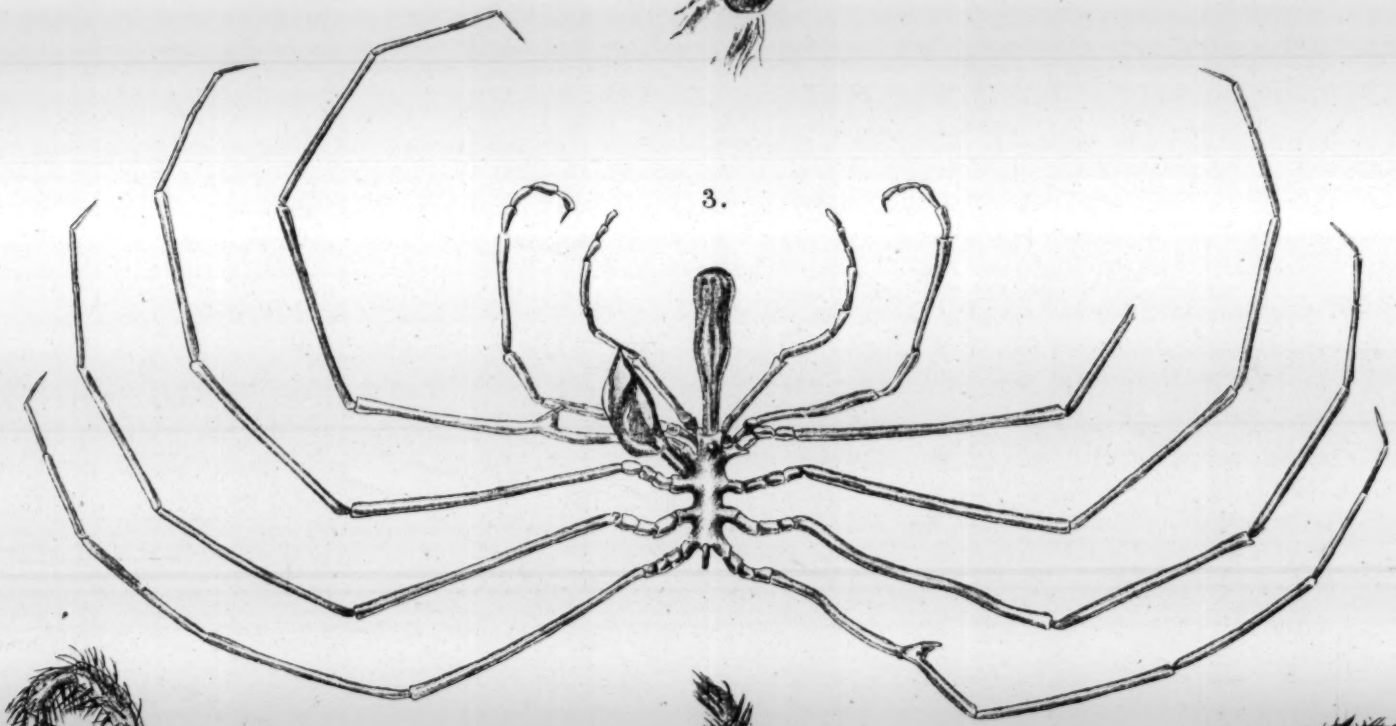
Mc Farlane & Erskine Lith Edin.r

HODGSON: PYCONOGONIDS.—PLATE II.

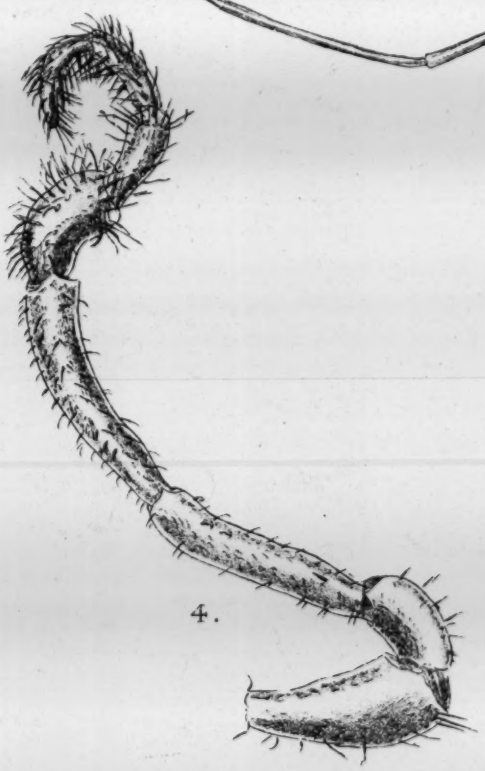
1.

1,*a*.

2.



3.



4.

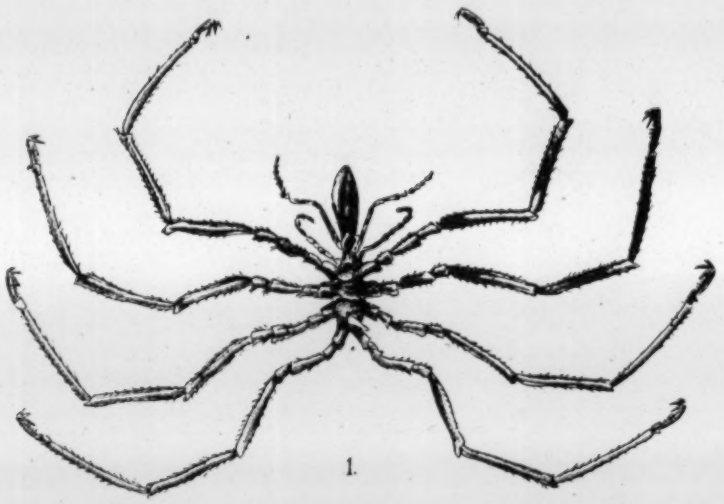
4,*a*.

2,*a*.

James Ritchie, del.

M.c Farlane & Erskine Lith. Ed.r

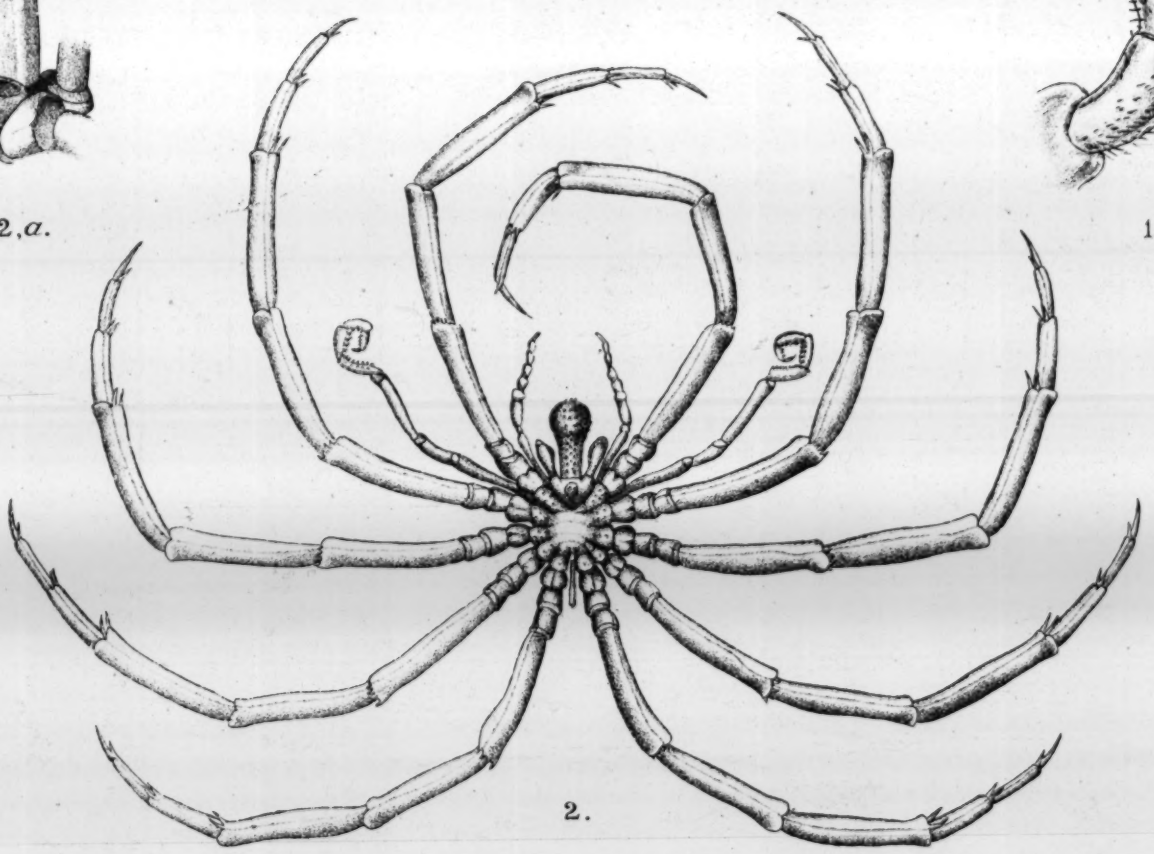
HODGSON: PYCONOGONIDS.—PLATE III.



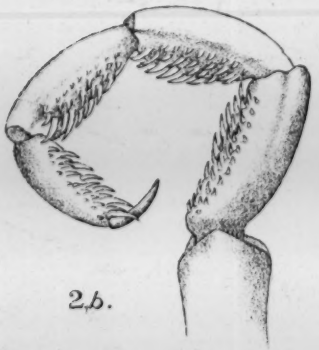
1.

2,*a*.

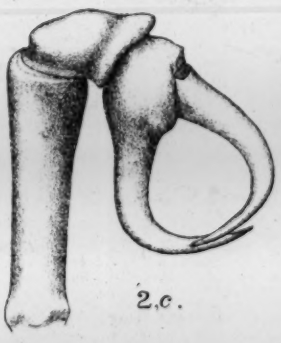
1,*a*.



2.



2,*b*.



2,*c*.

James Ritchie, del
E. W. Sexton, del. Fig 2, 2*a*, 2*b*, 2*c*.

M^c Farlane & Erskine Lith. Edin^r

# VII.—Scottish Rotifers, collected by the Lake Survey (Supplement).

By **James Murray.** (With Two Plates.)

(MS. received November 8, 1907. Read November 18, 1907. Issued separately February 10, 1908.)

## Introduction.

In June 1906 there was published an account of the Rotifers collected in the Scottish lochs up to that date (7). Many Rotifers had been observed during the survey of the lakes which are not referred to in that paper, as they were not collected actually in lakes. It is with the object of recording these species, and especially of giving an account of some interesting forms previously unknown or imperfectly known, that this supplementary paper is written. These Rotifers were, almost without exception, collected from moss, and, as is always the case in these circumstances, the Bdelloida greatly preponderated over the other orders.

Lists are given of the species found in the various islands visited—North Uist, Orkney, Shetland,—as an assistance to students of distribution, though there is little of special interest in these lists. The list from North Uist contains none but very common species, but in Orkney and Shetland there were a number of rare and interesting species.

Two animals have been found with sufficient frequency on mountain-tops to suggest that they may be specially adapted to the climate of such situations. They are *Callidina cornigera* and *C. plicata*, var. *hirundinella*. Both extend into the most northerly lands—the former to Spitsbergen, the latter to both Spitsbergen and Franz Josef Land.

## Rotifers of the Scottish Lochs—Additional Species.

Since the previous list was issued (7), nine additional species have been observed in our lakes, and one distinct variety :—

*Callidina tridens*, Milne. Loch Tay ; St Mary's Loch.

*C. constricta*, Dig. Frequent.

*C. musculosa*, Milne. Loch Ness.

*Rotifer hapticus*, Gosse. A stout brown animal with stout antenna, common in Loch Ness, seems to answer sufficiently to Gosse's description. The heavy antenna, narrowed towards the base, resembles that of *Callidina armata*, Murray (6). It is placed very far forward on the head in the creeping attitude. It is terminated by what appears to be a single seta, but may be a pencil of setæ. Otherwise the animal has a strong resemblance to *R. macroceros*, Gosse, and I have a suspicion that it is that

species with the antenna partly retracted. Gosse was evidently aware of the close affinity of the two species, as his description aims at discriminating them.

*Synchæta grandis*, Zach. Castle Semple Loch, Renfrew.

*S. oblonga*, Ehr. Frequent in small lochs and reservoirs.

*Diaschiza eva*, Gosse. Loch Ness.

*Brachionus urceolaris*, Ehr. Lochrutton, Dumfries.

*B. angularis*, Gosse. Several small lochs near Dumfries.

*B. pala*, Ehr., var. *dorcas* (Gosse). Hogganfield Loch, near Glasgow.

### Rotifers found in Ponds and Ditches.

This short list is not a complete account of the Rotifers collected by the Lake Survey in ponds, but only of those pond species which did not also occur in lakes. A large number of species were got in ponds, including the majority of the species recorded for the Scottish lochs. *Callidina natans*, a pond species, has already been recorded (6).

*Floscularia cornuta*, d'Ud. Bog pool on Blantyre Moor, near Glasgow.

### *Philodina convergens*, sp. n. (Plate I. figs. 1 to 3).

*Specific characters.*—Of moderate size; diameter of corona equal to or slightly exceeding first cervical segment; collar prominent, dorsal folds ending below summit of upper lip; sulcus between discs narrow, bottom convex, central setæ on discs. Rami much constricted at teeth, with prominent spine behind; teeth 2/2. Antenna short. Foot four-jointed. Spurs moderately long, with straight interstice, expanded at base; upper part almost parallel-sided, abruptly acute. Dorsal toes much smaller than ventral.

Length, feeding, 240 to 280 $\mu$; creeping, 333 $\mu$. Colour reddish. Trunk closely longitudinally plicate. Diameter of corona, 50 $\mu$; jaw, 25 $\mu$ long; spurs, 22 to 25 $\mu$ long. The rostrum is short, and no long tactile setæ were seen. Length of antenna equal to half the diameter of the first cervical segment.

Pale brown eyes. Stomach walls with yellow globules.

*Habitat.*—In washing of moss from the river Lochy, Killin, January 1906; quarry at Nerston, East Kilbride, February 1906.

In both localities the washing contained many *Gammarus*, and *Gammarus* parasites (at Killin *Phil. hamata*, at Nerston *P. laticeps*), so there is at least a suggestion that this is also a parasite. The corona is usually carried with the discs approximated as in *P. laticornis*, but can be pretty widely extended.

The points which distinguish this from other *Philodinæ* may seem rather slight, but close attention to them will show that it is quite distinct. The spurs, though narrow, are of the same form as in *P. laticeps*, etc., that is, blade-shaped. All the

species of the central group have more gradually tapering spurs. It is nearest *P. laticornis*, from which it is distinguished by the much shorter foot, slender spurs, and oviparous reproduction. The marked constriction of the jaws above the middle, and the posterior spine, are shared by no other species. All have a prominence at the back of the ramus, and in some it might be called a tooth or blunt spine, but none have such a prominent spine. This is only exceeded in size, among species known to me, in an undescribed African *Callidina*.

*Rotifer macrurus*, Schrank. Common in the mud of ponds, and especially so in peaty bog pools.

*Proales werneckei*, Ehr. Parasite in *Vaucheria*, on which it forms galls; roadside ditch, Blantyre Moor, near Glasgow.

*Diglena rosa*, Gosse. Ponds, Pomona, Orkney.

*Rattulus carinatus*, Ehr. Peaty pools, Blantyre Moor.

*R. bicristatus*, Gosse. Pools, Blantyre Moor.

*Elosa worrallii*, Lord. Pools, Blantyre Moor.

*Stephanops muticus*, Ehr. Pools, Blantyre Moor.

*Diaschiza exigua*, Gosse. Pond near Mallaig, Inverness-shire.

*Pterodina mucronata*, Gosse. Pond at Nerston, near Glasgow.

## Rotifers found among Moss.

Moss in any situation is likely to contain abundance of Rotifers. In most situations Bdelloids will predominate, but *Sphagnum* will harbour many other kinds. As a rule the Bdelloids are indifferent to the situation of the moss, and many kinds are found alike in moss which is always moist (*Sphagnum* and mosses in streams, etc.), and in that which is only intermittently moist (on the ground, walls, trees, rocks, etc.).

A few species are exceptions to this rule. *Microdina paradoxa*, for example, will only be found in fresh or running water. The symbiotic species, supposed to be confined to certain hepatics, are quite common in other situations, as among *Sphagnum*.

*Callidina microcephala*, Murray. Ground moss, Fort-Augustus.

## *Philodina brycei* (Weber) (8).

One of the commonest Bdelloids in Scotland is *P. brycei*, and it is often found in lochs. It is subject to a great deal of variation.

Weber's description of *Callidina brycei* (8, p. 347) is in the following terms:—"Le corps est robuste, allongé, de coloration grisâtre ou brunâtre. La peau est rugueuse, sillonnée de forts plis longitudinaux sur les faces dorsale et latérales du corps; par contre, on compte 8 plis transversaux sur la face ventrale. Le bord antérieur du premier segment troncal et le bord postérieur du troisième segment troncal sont armés chacun, dorsalement et latéralement, d'une rangée de courtes épines. L'organe rotatoire est modérément large, à sillon intertrochal étroit. La trompe cylindrique est longue.

L'antenne dorsale est longue et formée de deux articles. Le pied est court, épais. Les éperons courts, coniques sont peu distants l'un de l'autre. Formule dentaire 2/2."

WEBER remarks the resemblance to *Callidina alpium*, Ehr. (which I transfer to *Philodina*). The resemblance is extremely close. Size, colour, general form, skin-folds, —all are alike in the two species. Imagine *P. brycei* deprived of its short central and anterior spines, and we could not, I believe, distinguish it from *P. alpium*.

The type of the species has never occurred in our collections in Scotland, but several varieties are common. The common Scotch form which comes nearest the type differs in having two short spines on the posterior part of the trunk. These appear to be on the preanal segment, but I believe they are really on the fourth central.

The spines on the anterior border of the trunk do not form a regular equal series, as in WEBER's figure. The pair nearest the middle of the back are longest, and form a fork in which the antenna rests when the animal is feeding, precisely as in *Brachionus*, *Anuræa*, etc.

The next pair of spines are very small points. The last pair are laterally placed, or a little inclined to the ventral side. Each of them is usually furcate, one point (the lateral one) being erect, and the other (more ventral) spreading or decurved.

There are some other small spines usually present, which are not referred to by WEBER. On the two lateral skin-folds of each side of the central trunk, on which are the last spines of the transverse dorsal row, there are small spines a little in front of those. Sometimes only one lateral fold has this spine.

This form is generally distributed in Scotland. It is not figured here, but fig. 13, which is of another variety, indicates all the structures referred to, but has an additional transverse row of spines.

*Variety* (fig. 13).—This differs from the form just described in possessing a second transverse row of spines on the central trunk, a little behind the main row. There are four spines in this row. The anterior processes forming the fork for the antenna are very large and are frequently furcate. Almost as common in Scotland as the other, and widely distributed over the world. In Indian examples there may be six or eight spines in the secondary transverse row.

### *Callidina cornigera*, Bryce (2).

In 1893 Mr BRYCE described this species in the following terms (p. 201):— "Trochal discs apparently without gap, laterally produced into two horn-like but fleshy processes, whose bases are furnished on inner face with cilia, forming part of principle wreath. Antenna very short, one-fourth of neck thickness. . . . *Length*, extended, about $\frac{1}{100}$th inch." He noticed further that "the double flap terminating the column tip (lamellæ) was rather more developed than usual," saw the usual skin-folds and conical spines, but failed to make out the dental formula.

These observations were made on a single example, which, though kept alive for

the long period of fourteen days, appears never to have given very good opportunity for study.

The original specimen was found among moss from roadside, near Bognor, Sussex. Some years later another example was found in moss from Buckinghamshire. In 1897 a third example appeared in moss from Spitsbergen. On this occasion Mr BRYCE observed the dental formula 2/2, and gives the measurement of the extended animal as 0·347 mm., but adds nothing further to his original description. In the plate accompanying the description the jaws are figured with two teeth in each.

WEBER (8) found two examples of the species, in very bad condition. His description (p. 349) is almost identical with BRYCE'S, and he adds nothing of importance except the dental formula 2/2. He says that the lamellæ are broad.

I can find no other record of the species, which would seem to indicate that it is a rare animal, as such an extraordinary creature would readily attract attention. In March 1904 I first found it in moss from the shore of Loch Ness, near Fort-Augustus, and subsequently it has appeared pretty frequently in Scotland, permitting fuller studies to be made of it.

There will hardly, I think, be any doubt as to the identity of the animal found in Scotland, if the figures here given (Plate II. figs. 20 to 26) are compared with those of BRYCE and WEBER, although I am compelled to differ from Mr BRYCE as to the most important structures of the animal, the horns and the discs. According to BRYCE, the discs have apparently no gap, and are produced into the horns, and the bases of the horns are ciliated, the cilia forming part of the principal wreath.

I find that the discs are normal and separate, but close together, and the horns spring from folds of skin somewhat to the dorsal side of the discs (technically part of the collar, I believe). The horns are nowhere ciliate.

These differences between Mr BRYCE'S observations and mine seem greater on paper than they are in reality. Compare the figures, and see what a slight difference in interpretation is involved.

A full description of the animal, as observed in Scotland, is added.

*General form.*—Slender, more like WEBER'S figure than BRYCE'S, broadest in central trunk, well-marked neck, slightly expanded head, much contracted in posterior trunk (4th central), foot generally hidden. Trunk closely longitudinally plicate. In its movements the animal contorts its body a good deal, changing form greatly, expanding one segment and drawing in another.

*Discs.*—Elliptical, touching at inner margin, slightly inclined forward.

*Horns.*—Long, white, with broad bases and narrow, soft, blunt tips, curved forward from base to apex, and elbowed where the narrow part begins, sometimes angled again, or incurved close to the apex. One horn is generally longer than the other, and in the creeping attitude the tip of the longer one usually protrudes, sometimes both.

There is no doubt that the function of the horns is tactile. The animal is exceedingly sensitive and timid. The horns are employed before beginning to feed, and

their action is very like that of fingers. Arrived before some flocculent material, the head is unfolded in a hesitating manner, the horns (or fingers) make a tapping motion forward among the food-material, after which the beast either withdraws into its trunk hurriedly, or goes on quietly feeding. The fingers seem to be moved by special muscles, and act as if articulated at the bend, though nothing of this was actually seen.

*Rostrum.*—The basal joint is large, the apical joint very small and short.

*Lamellæ.*—These exhibit the highest development of the Bdelloid lamellæ known. They are very large, and widely divergent laterally, resembling a pair of butterfly's wings. Unlike those of most Bdelloids, which remain passively motionless when extended, the lamellæ of *C. cornigera* are waved about in the water with a very graceful motion. This action has suggested that they are organs of smell.

*Rostral cilia.*—The brush of cilia is well developed, but none of the other processes of the tip were seen.

*Antenna.*—This is very short. In the creeping attitude it looks like a little button (fig. 22), or may be quite retracted. It can be extended to about one-quarter the diameter of the neck.

*Stomach.*—Walls much convoluted, food moulded into pellets. Though neither Bryce nor Weber mentions this, their figures seem to indicate that they observed it.

*Intestine.*—Rarely easy to observe in a pellet-maker, it was here conspicuous and filled with pellets.

*Jaws.*—Teeth 2/2. Lateral margin lightly convex, angled to anterior margin; posterior margin abruptly bent, forming a little point (fig. 25).

*Foot.*—Joints, four. Spurs small, acuminate, curved, close at bases. Toes, three, short, blunt.

*Yelk-mass.*—Eight relatively large nuclei.

*Egg.*—Small, thin-shelled, shortly oval.

*Habitat.*—Among moss, most commonly *Sphagnum*, from near sea-level to nearly 4000 feet. Shores of Loch Ness, several places; Ben Lawers; East Kilbride, near Glasgow; Orkney, summit of Ward Hill, in Hoy, about 1500 feet.

Length, creeping, 250 $\mu$. This is the same size as Mr Bryce's first example, but that from Spitsbergen was much larger.

### *Callidina minuta*, sp. n. (Plate I. figs. 11, 12).

*Specific characters.*—Very small. Very short, with broad trunk. Corona less than neck, much less than collar. Central trunk broadly elliptical, first segment anterior to central trunk bearing some small spines on lateral skin-folds. Posterior part of trunk nodose. Foot short; spurs short, acuminate, meeting at bases. Teeth about 5/4 (5/5, 4/3). Food moulded into pellets.

In form this curious little animal is an exact miniature of *C. pulchra*, Murray (6). The only differences in detail which can be pointed out are that the first cervical does

not project so prominently outward in *C. minuta*, and the little lateral spines on the anterior trunk segments. The skin was not stippled, but little importance can be given to that character.

In size it does, however, differ greatly, measuring only 77 $\mu$ in length when feeding, or little more than one-third that of *C. pulchra*. While size alone cannot be made a primary specific character, in this case the difference between the related species is so great that it gives greater weight to the other small differences.

No Bdelloid which I have seen hatched is to such a degree smaller than the adult. In common with many other Rotifers, the young, when hatched, is hardly inferior in length to the parent, and very soon attains to all the adult proportions. The pellets of food which filled both stomach and intestine showed that the last example of *C. minuta* had been feeding for a considerable time. The pellets are relatively large, measuring 6–7 $\mu$.

The discs are inclined backward, and have central setæ. The spurs measure 9 $\mu$ from tip to tip.

The length of the antenna is equal to one-third of the diameter of the neck.

*Habitat.*—Among *Sphagnum*, Blantyre Moor, 1902. In ground moss, Nerston, near Glasgow, March 1905.

On the first occasion of finding it, my acquaintance with Bdelloids was very limited, and after a time I lost faith in the observation, and came to suppose that there had been a mistake as to the power of the microscope used. The second occurrence of the animal, years later, after a good deal of experience among Bdelloids, confirmed the earlier record.

*Callidina circinata*, sp. n. (Plate I. figs. 4 to 10).

*Specific characters.*—Small. Head nearly square, with corona slightly exceeding the collar, and very prominent dewlap overhanging first neck-segment. Upper lip of very unusual form—sulcus between discs deep, bounded by two large processes connected with the collar (the arrangement will be better understood from fig. 5 than from any description). Antenna short, dorso-lateral processes large, widely spreading laterally. Foot short, three-jointed. Spurs large, long, nearly parallel-sided, incurved, acute, interspace large, flat. Toes symbiotic (joined to form a perforate disc). Teeth, 3/3 or 2+1/1+2. Length when feeding, 213 $\mu$; diameter of trunk, 71 $\mu$; of corona 60 $\mu$; tip to tip of spurs, 30 $\mu$.

*Habitat.*—Among moss growing on dry wall at Nerston, East Kilbride, October 1906. Plentiful.

This species affords another of those puzzles in distribution which are especially familiar to students of the Rotifera. The moss on the wall was growing in little detached cushions. One of these was casually pulled in passing, and was washed on reaching home. When the strange species was found so abundant in it, the wall was visited again, and surrounding tufts pulled, but none of the Rotifers found.

The long spurs, more or less curved towards one another, resemble callipers. The flame-cells are narrow and spindle-shaped. The rostrum is short and broad. The dorso-lateral processes of the neck are conspicuous in the creeping attitude (fig. 6). Length of antenna about equal to half diameter of neck.

The possession of a "symbiotic" foot, *i.e.* one ending in a perforate adhesive disc, distinguishes *C. circinata* from the great majority of *Callidinæ*. Of the small group having a foot of this type, all have a greater number of teeth, except only *C. symbiotica* and *C. armata*, and both of these species have short spurs of quite a different shape, so that the species cannot be confused with any known species.

*Callidina plicata*, Bryce (1).

Described by Bryce in 1892. The most important distinguishing character is the expanded, hood-like, posterior trunk-segment.

One of the very commonest Bdelloids in Scotland, *C. plicata* is the centre of a large series of forms, some of which have the processes of the posterior trunk-segment greatly produced, while others have them reduced or entirely absent. The latter would not be recognised as *C. plicata*, but long study of other characters of the type, and of a series of forms in which the processes were progressively reduced, convinced me that those without the processes were also of this species.

*Description of C. plicata* (type) (fig. 14).

*General form* narrow, elongate, widest in central trunk. Neck and anterior trunk well extended in usual feeding attitude. Trunk closely plicate, the central dorsal pair running out on to the rump, as pointed out by Bryce; but the rump is marked off from the central trunk by a very deep transverse furrow, so that the longitudinal folds on the rump might more properly be regarded as distinct from those of the central trunk.

The transverse furrow is much further forward than the lateral constriction separating rump and central trunk, but I believe both belong to the same line of separation of segments.

*Head.*—From the neck the head gradually expands upward, the corona being the widest part. The collar is distinct, but not very prominent. The discs bear central setæ, springing from small papillæ.

*Upper lip.*—Though to some extent variable, the upper lip is one of the best characteristics of the species. There are two convex processes, meeting in the middle line, much as in *C. habita* (3). Between them is usually a smaller convexity, not belonging to the lip. The processes are connected with the collar by a ridge, as usual. From the outer edge of the processes two fine lines pass downward towards the rostrum, converging towards the middle line, giving the lip the appearance of a keystone set into the head. This form of lip I have seen in no other species.

*Rostrum.*—Short and broad, and bearing two lamellæ, which in dorsal view seem far separated, as in some symbiotic *Callidinæ*. The restlessness of the animal when not

feeding has prevented a fuller study of the rostral processes; but I have thought at times I could detect long setæ, or pencils of setæ, projecting laterally from the lamellæ, as in *C. ehrenbergi*, Janson (4).

*Vibratile tags.*—These are of the usual narrow form. I have not been able to count more than four pairs.

*Alimentary canal.*—The jaws, stomach, and intestine are normal. There are two teeth in each jaw, and the usual fine striæ. The food is not moulded into pellets.

*Rump.*—The preanal and anal segments, which form the rump, are but slightly separated; but the second constriction mentioned by BRYCE doubtless marks the separation, and the hood with its processes will then belong to the anal segment. The two lobes which project from the end of the anal segment are thin hyaline flanges.

*Foot* of four joints, short. Spurs rather long for a *Callidina* of the central group, narrow, tapering, slightly acuminate, obtuse, close together at base, but small interspace showing in some positions. Toes very short, difficult to see, as the last portion of the step is very rapidly made.

*Variations of C. plicata.*

*Head.*—The processes of the upper lip, which usually meet in the middle line (fig. 14), are sometimes separated by a small but deep sulcus. A *ligule* is very commonly present, in examples otherwise typical (see dotted line between the discs in fig. 15). In its greatest development this is a drop-shaped body, apparently just touching the head, a little to the ventral side of pedicels.

*Foot.*—The first foot-joint sometimes has a boss, which may be centrally placed, as in most species having this process, or at the posterior edge of the segment, as in *C. symbiotica*. In an Indian form, not otherwise peculiar, this becomes a transverse ridge, with a sharp edge.

*Rump.*—BRYCE does not refer to the processes on the posterior margin of the *hood*, but his figure shows them.

Their commonest form is shown (in fig. 14). A form in which they are quite obsolete is figured (fig. 19). The posterior part of the hood is divided into three plane surfaces, a central one and two lateral flaps.

The processes are, on the other hand, often produced much more than in that figured (fig. 14), and become in some forms very prominent. They are still, however, quite rigid outgrowths of the skin, and do not appear to be articulated at the base.

A form in which the development of these processes is carried still further is regarded as being a stable variety, and is described below.

*C. plicata*, Bryce, var. *hirundinella*, var. nov. (Plate II. figs. 16 to 18).

*Distinctive characters.*—The processes on the anal segment are produced into long ligular bands with rounded ends. They normally diverge widely, but they are distinctly articulated at the base, and can be approximated, or even crossed over one

another (fig. 18). These tail-like processes suggest a resemblance to those of the swallow-tail butterfly. They are sometimes considerably longer than the foot. I have seen no evidence that they are movable at will, but they certainly yield readily at the base and assume many different positions. The position in which they are crossed does not seem one likely to be produced automatically by the movements of the skin to which they are attached.

*Habitat.*—Among ground moss. Frequent, especially on mountain-tops. Fort-Augustus; Ben Lawers (cairn on summit); North Uist; summit of Ward Hill in Orkney, and of Ronas Hill in Shetland.

*Rotifer quadrioculatus*, Murray. Moorland, Fort-Augustus.

*Arthroglena lutkeni*, Berg. Moorland, Pomona, Orkney.

*Stephanops microdactylus*, Murray. Blantyre Moor; Ballagioch Hill, near Glasgow.

*Cathypna ungulata*, Gosse. Mainland of Shetland.

*Brachionus bakeri*, Ehr. Summit of Ronas Hill, Shetland.

### Rotifers found in the Sea.

Though the Rotifers are pre-eminently a fresh-water group of animals, a considerable number of marine species are now known. Besides those which are exclusively marine, many species live indifferently in fresh or salt water. Seaweed was gathered on the west coast of Scotland, kept tightly packed in a tin box for a week, then washed in fresh water. A great many living Rotifers were then found which seemed active and healthy in the fresh water.

The Lake Survey did not make a special study of the marine species, but occasionally, when opportunity offered, the nets were used in the sea, or seaweed was washed.

*Synchæta* is a specially marine genus, or at least has a number of exclusively marine species. In the harbour at Mallaig we found one species extremely abundant, and in the brackish loch of Stenness there were several species; but we could not venture to name these without submitting them to a specialist. We have found only one Rotifer in the sea which has never occurred in fresh water.

*Rattulus dubius* (Lauterborn) (5). In Morar Bay, West Inverness. Got by washing seaweeds.

*Furcularia reinhardti*, Ehr. This common lake species was also frequent in the sea at Morar. The salt-water form was larger than the other, but I could see no other difference.

*Philodina.* Two species occurred in the washings of seaweed from Lochinver, West Sutherland. They could not be identified. (*P. flaviceps*, Bryce, was got by Mr Wm. Evans in the sea near Edinburgh.)

*Colurus*, sp. In the washings of seaweed, one of the species occurring most regularly is a large *Colurus*, which I will not attempt to name, in the present chaotic state of the genus.

*Pterodina*, sp. Lochinver.

## Rotifers of North Uist.

The Rotifers enumerated in the following short list were collected in the early summer of 1904, while the lochs of the island were being surveyed. As the whole district surveyed is one great wet moor, most of the Rotifers were got from bog or moor mosses, chiefly *Sphagnum* and *Hypnum* of various species.

One interesting collection was made from a tuft of *Fontinalis* growing in a mill-stream, within reach of the tides, so that the animals living in the axils of the leaves must be able to endure alternately fresh and salt water. The species found here were *Philodina flaviceps*, and all four species of *Euchlanis* on the list. *P. flaviceps* has since been found actually in the sea, by Mr Wm. Evans.

*Philodina rugosa*, Bryce.
„ *nemoralis*, Bryce.
„ *flaviceps*, Bryce.
„ *macrostyla*, Ehr., and variety *tuberculata* (Gosse).
*Callidina aspera*, Bryce.
„ *lata*, Bryce.
„ *angusticollis*, Murray.
„ *symbiotica*, Zel.
„ *tetraodon*, Ehr.
„ *russeola*, Zel.
„ *plicata*, Bryce, and variety *hirundinella*.
„ *papillosa*, Thompson.
„ *multispinosa*, Thompson.
„ *quadricornifera*, Milne.
*Rotifer tardus*, Ehr.
„ *macrurus*, Schrank.
„ *citrinus*, Ehr.
*Adineta vaga*, Davis.
*Adineta barbata*, Janson.
*Ascomorpha ecaudis*, Perty.
*Microcodon clavus*, Ehr.
*Copeus cerberus*, Gosse.
*Proales petromyzon*, Ehr.
*Furcularia longiseta*, Ehr.
*Rattulus longiseta*, Schrank.
*Diurella tigris*, Müll.
*Diaschiza gibba*, Ehr.
*Dinocharis tetractis*, Ehr.
*Stephanops muticus*, Ehr.
*Euchlanis lyra*, Huds.
„ *oropha*, Gosse.
„ *deflexa*, Gosse.
„ *triquetra*, Ehr.
*Monostyla lunaris*, Ehr.
„ *cornuta*, Ehr.
*Colurus obtusus*, Gosse.
*Anuræa serrulata*, Ehr.

## Rotifera of Orkney and Shetland.

As I am aware of no published account of the Rotifers of these islands, a list of some of those found by the Lake Survey is here given, though there is nothing of special interest in the list. We found several species which are very local in their distribution, some of them only previously known from one or two spots on the mainland of Scotland. Though the majority of Rotifers are considered to be cosmopolitan in their distribution, the same species appearing under similar conditions everywhere, the portion of the earth's surface which has been carefully examined is too limited to permit us to suppose that this is demonstrated, and so local lists have their uses.

*Arthroglena lutkeni*, Berg., occurred in Orkney, and *Brachionus bakeri*, Ehr., in Shetland, both for the first time in my experience. The lists from Orkney and Shetland are given in parallel columns, though the information thus given is of little value, owing to the inadequacy of the work done. As usual, the great majority of the species found are Bdelloids. Forty-four species and three varieties are noted for Shetland, thirty-two

species and one variety for Orkney. Twenty-three species and one variety are common to the two groups.

The two highest hills in the islands, Ward Hill in Hoy and Ronas Hill in Shetland, were specially examined. Both are about 1500 feet in height, and thus combine high latitude and considerable elevation. Saxavord Hill, in Unst, nearly 1000 feet high, and close to the northernmost point of the British Islands, was also carefully studied.

| | Orkney. | Shetland. |
|---|---|---|
| *Philodina aculeata*, Ehr. | | Ronas Hill, Mainland. |
| „ *macrostyla*, Ehr. | | Mainland; Yell. |
| var. *tuberculata* (Gosse) | | Mainland; Yell. |
| „ *acuticornis*, Murray | | Ronas Hill; Yell. |
| „ *brevipes*, Murray | Ward Hill, Hoy. | Ronas Hill. |
| „ *flaviceps*, Bryce | | Yell. |
| „ *nemoralis*, Bryce | Hoy; Rousay | Unst. |
| „ *rugosa*, Bryce | Ward Hill, Hoy. | Ronas Hill; Yell. |
| „ *alpium* (Ehr.) | | Saxavord, Unst. |
| „ *brycei* (Weber). | Rousay | Mainland. |
| „ *humerosa*, Murray | | Mainland. |
| *Callidina aspera*, Bryce | Rousay | Mainland; Yell; Unst. |
| „ *rœperi* (Milne) | | Mainland. |
| „ *angusticollis*, Murray | | Saxavord, Unst. |
| „ *lata*, Bryce | | Ronas Hill. |
| „ *pulchra*, Murray | Pomona. | ... |
| „ *constricta*, Duj. | Ward Hill, Hoy. | ... |
| „ *tridens* (Milne) | Pomona. | ... |
| „ *leitgebii*, Zel. | Hoy; Rousay | Saxavord, Unst. |
| „ *cornigera*, Bryce | Ward Hill, Hoy. | ... |
| „ *plicata*, Bryce | Hoy; Rousay | Mainland; Yell; Unst. |
| var. *hirundinella*, var. nov. | Ward Hill, Hoy. | Ronas Hill. |
| „ *habita*, Bryce | Ward Hill, Hoy | Mainland. |
| „ *quadricornifera* (Milne) | Pomona; Rousay | Mainland; Yell; Unst. |
| „ *ehrenbergii*, Janson | Pomona | Yell; Unst. |
| „ *papillosa*, Thompson | Hoy; Pomona; Rousay | Mainland. |
| „ *musculosa* (Milne) | Pomona | Mainland. |
| „ *symbiotica*, Zel. | Pomona | Ronas Hill. |
| „ *armata*, Murray | Pomona. | ... |
| „ *tetraodon*, Ehr. | Pomona | Ronas Hill. |
| „ *incrassata*, Murray | Rousay | Mainland. |
| „ *scarlatina*, Ehr. | Ward Hill, Hoy | Ronas Hill. |
| „ *russeola*, Zel. | Ward Hill, Hoy | Mainland; Unst. |
| *Rotifer vulgaris*, Schrank | | Yell; Unst. |
| „ *macrurus*, Schrank | | Ronas Hill. |
| „ *citrinus*, Ehr. | | Saxavord, Unst. |
| „ *longirostris* (Janson) | Ward Hill, Hoy | Mainland; Unst. |
| *Adineta vaga* (Davis) | Pomona | Mainland. |
| var. *major*, Bryce | | Mainland. |
| „ *barbata*, Janson | Ward Hill, Hoy | Mainland; Unst. |
| „ *gracilis*, Janson | Pomona | Mainland. |
| „ *tuberculosa*, Janson | | Ronas Hill. |
| *Notommata toruloso* (Duj.) | | Mainland. |
| *Diglena rosa*, Gosse. | Pomona. | ... |
| „ *ferox*, Western | | Mainland. |
| *Arthroglena lutkeni*, Berg. | Pomona. | ... |
| *Stephanops stylatus*, Milne | Pomona. | ... |
| „ *tenellus*, Bryce | Pomona | Mainland. |

| | Orkney. | Shetland. |
|---|---|---|
| *Diaschiza eva*, Gosse . . . . | . . . . . | Mainland. |
| *Monostyla lunaris*, Ehr. . . . . | Ward Hill, Hoy . . . | Ronas Hill. |
| „ *cornuta*, Ehr. . . . . | Rousay. | ... |
| *Distyla flexilis*, Gosse . . . . | . . . . . | Mainland. |
| *Cathypna ungulata*, Gosse . . . . | . . . . . | Mainland. |
| *Colurus obtusus*, Gosse . . . . | . . . . . | Mainland. |
| *Metopidia acuminata*, Ehr. . . . | . . . . . | Ronas Hill. |
| *Brachionus bakeri*, Ehr. . . . . | . . . . . | Ronas Hill. |

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## EXPLANATION OF PLATES.

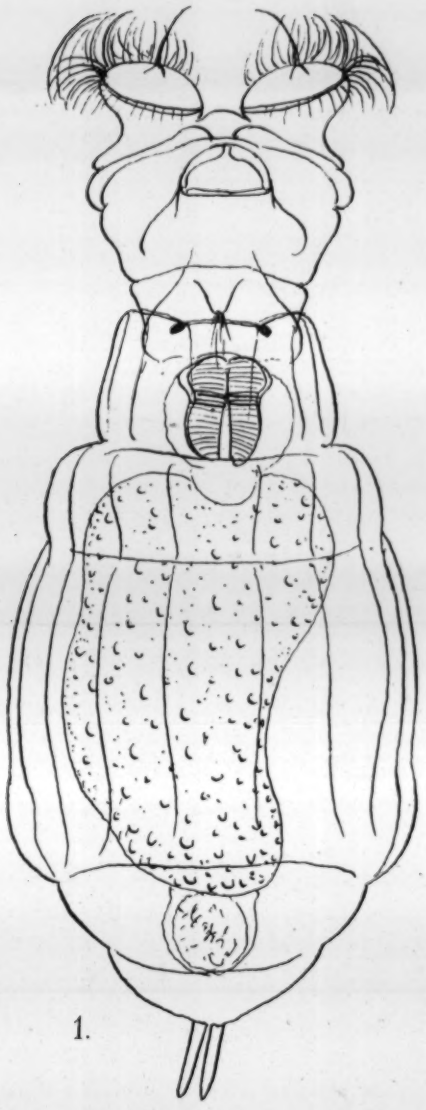
In order to indicate relative sizes of different species, all the drawings of complete animals are made to one scale, except that of *C. minuta*. To show sufficient detail, this had to be drawn nearly twice as large as the others.

### Plate I.

1. *Philodina convergens*, sp. n., dorsal view, feeding.
2. „ „ jaw, seen from behind.
3. „ „ spurs and toes.
4. *Callidina circinata*, sp. n., dorsal view, feeding.
5. „ „ head, more highly magnified.
6. „ „ head and neck, when creeping.
7. *Callidina circinata*, section of neck and antenna.
8. „ „ jaw.
9. „ „ foot.
10. „ „ spurs and perforate disc.
11. *Callidina minuta*, sp. n., dorsal view, feeding.
12. „ „ head more highly magnified.
13. *Philodina brycei*, Weber, variety.

### Plate II.

14. *Callidina plicata*, Bryce, type, feeding.
15. „ „ head, on larger scale.
16. „ „ var. *hirundinella*, var. nov., rump and foot, showing processes.
17. „ „ var. *hirundinella*, side view of foot.
18. „ „ var. *hirundinella*, showing processes crossed.
19. „ „ foot of variety without flanges on hood.
20. *Callidina cornigera*, Bryce, side view, feeding.
21. „ „ dorsal view, feeding.
22. „ „ head, seen from above.
23. „ „ side view of rostrum, lamellæ, and antenna.
24. „ „ dorsal view of rostrum and lamellæ.
25. „ „ jaw.
26. „ „ foot.



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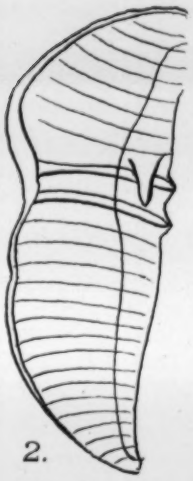

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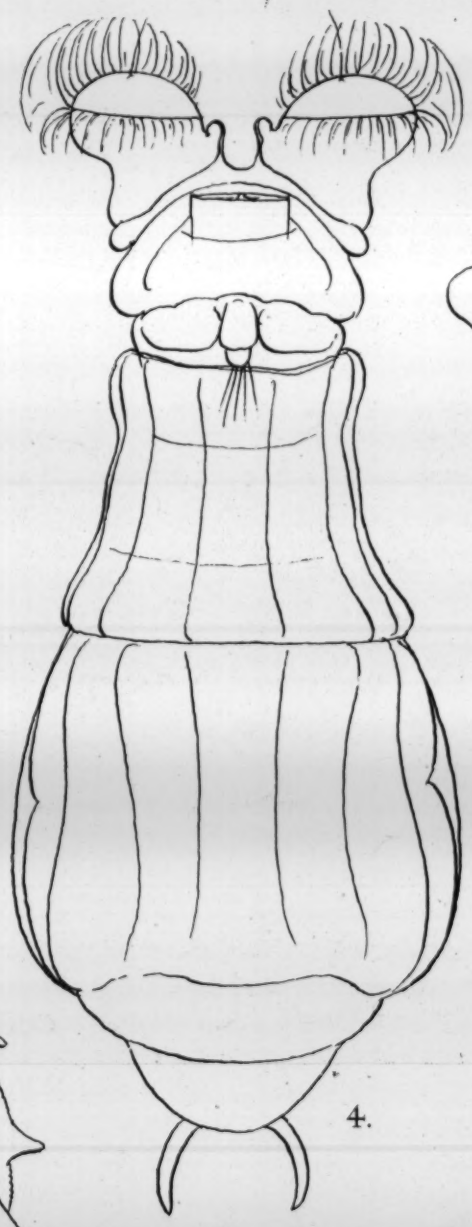

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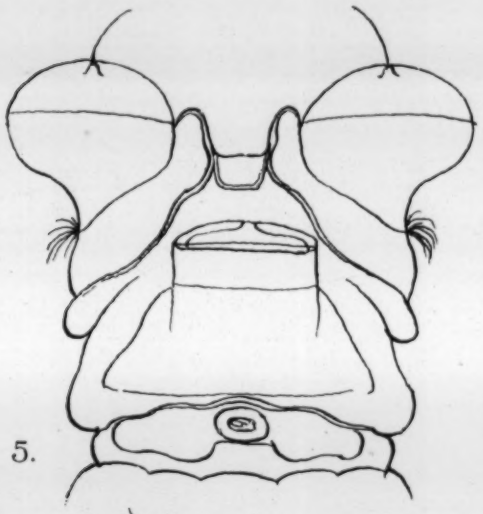

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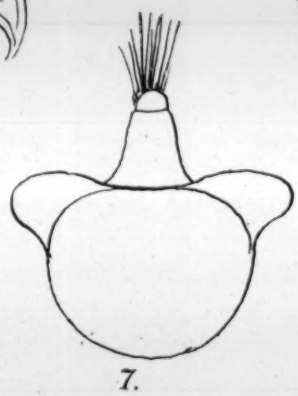

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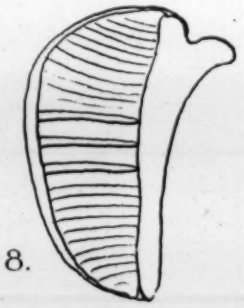

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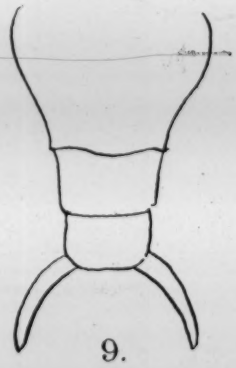

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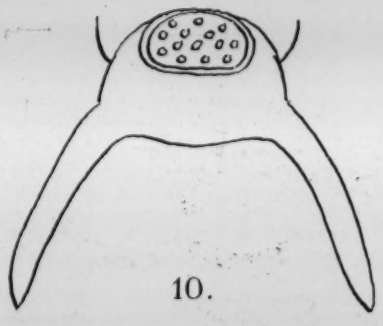

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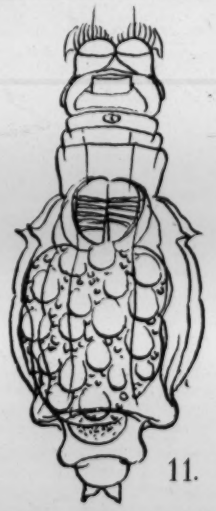

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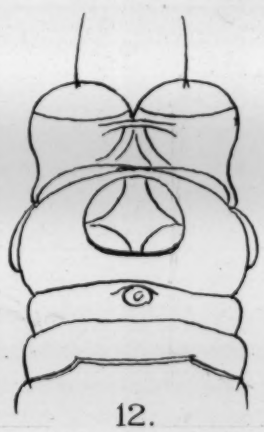

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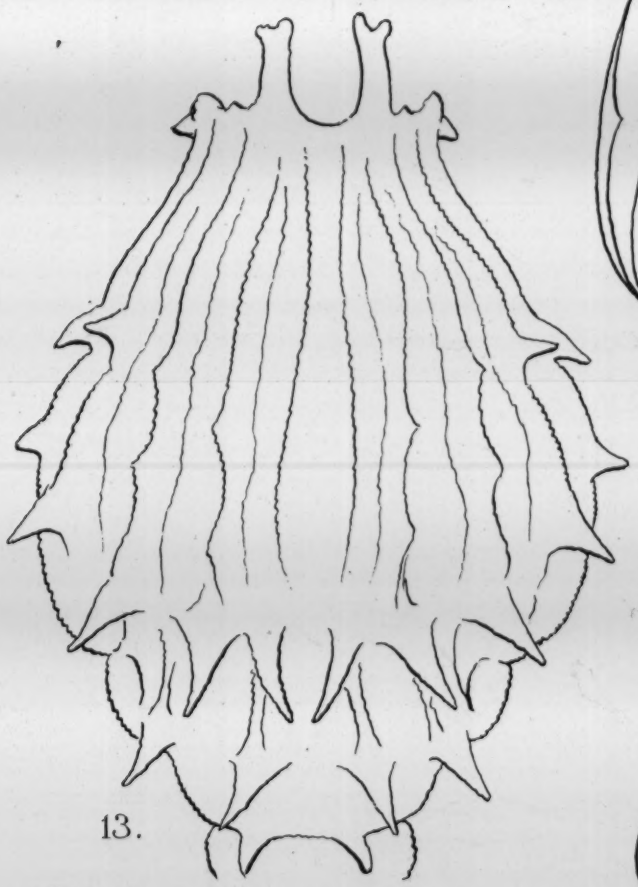
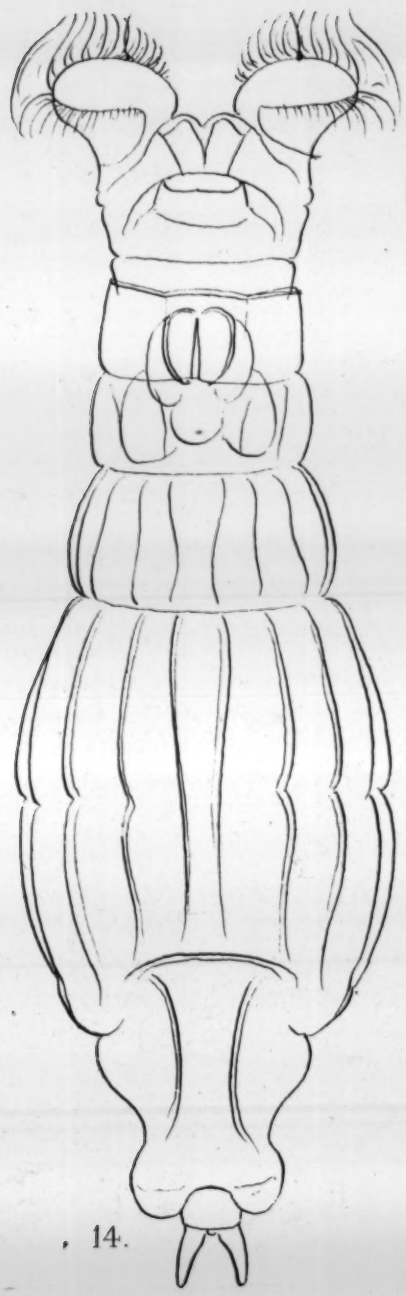


13.

J. Murray, del. ad. nat.

M^c Farlane & Erskine Lith. Edin^r

1-3, PHILODINA CONVERGENS, sp.n. 4-10, CALLIDINA CIRCINATA, sp.n. 11-12, C. MINUTA, sp.n. 13, P. BRYCEI. WEBER. var.



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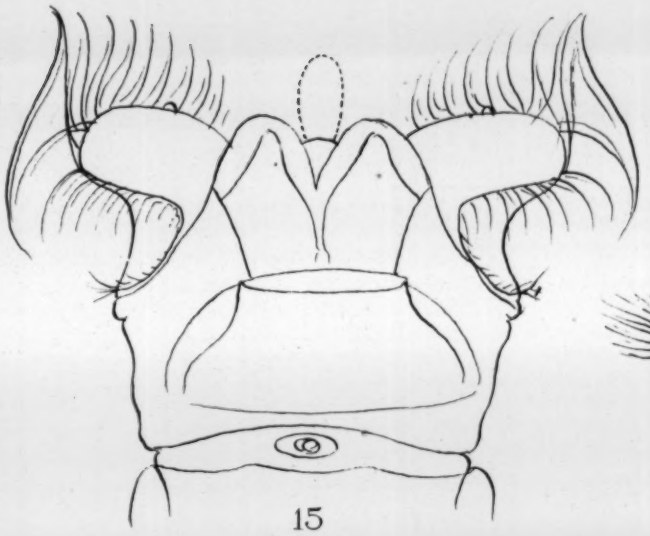

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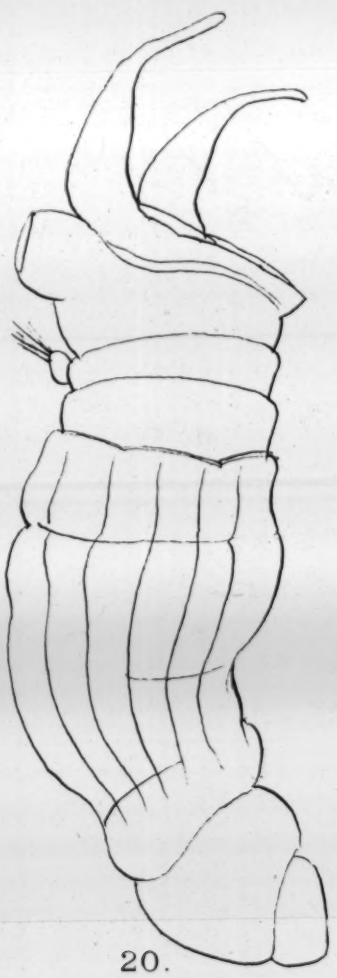

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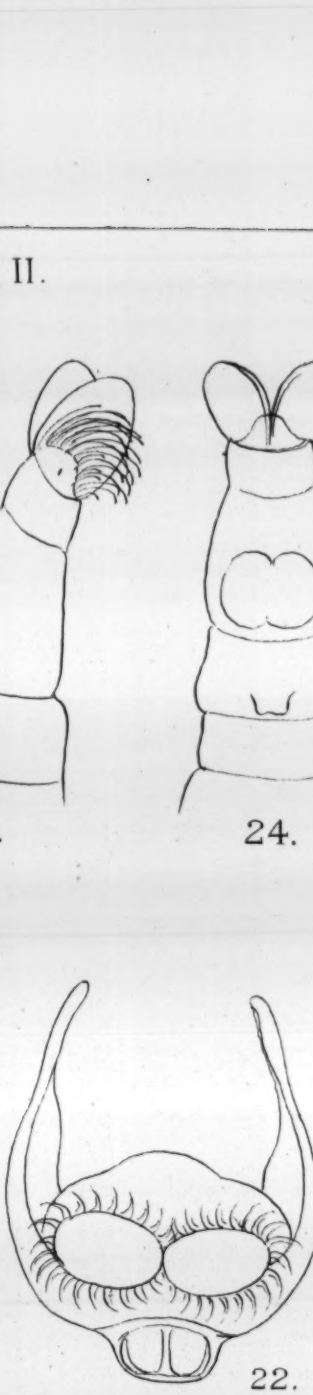

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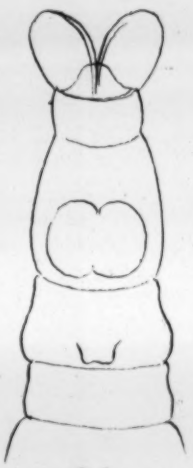

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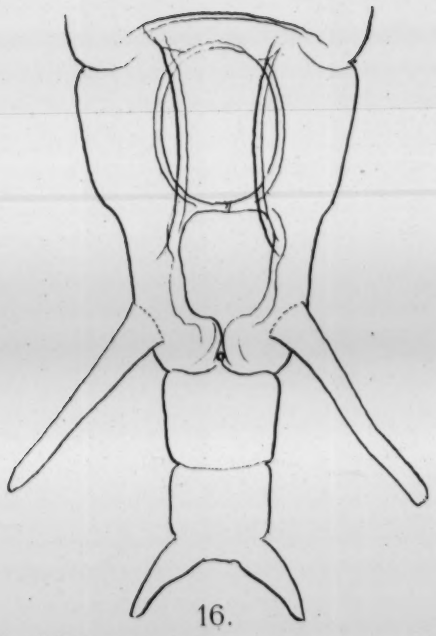

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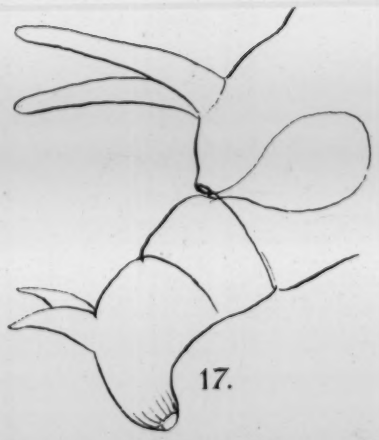

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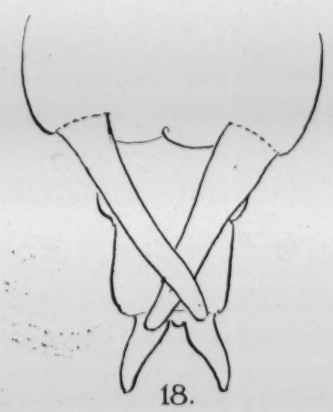

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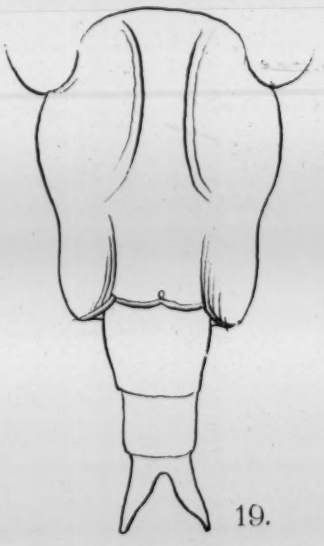

19.

J. Murray, del. ad nat.

M^c Farlane & Erskine Lith. Edin^r

14-19, CALLIDINA PLICATA, Bryce. 16-18 var. HIRUNDINELLA, var. nov. 20-26, C. CORNIGERA, Bryce.

# VIII.—On the Histology of the Ephedreæ, with Special Reference to the Value of Histology for Systematic Purposes.

By **R. J. D. Graham**, M.A., B.Sc., Carnegie Research Scholar, Botanical Department, The University, St Andrews. *Communicated by* R. A. Robertson, M.A., B.Sc., F.R.S.E., F.L.S. (With Three Plates.)

(MS. received April 30, 1907. Read June 10, 1907. Issued separately February 20, 1908.)

## Part I.—Primary Structure of Stem.

Although a few papers have been published a number of years ago on the genus Ephedra, the authors have treated the subject mainly from a systematic standpoint. Thus, while the characters of the floral organs have been carefully examined and described, the structure and character of the vegetative organs have only received passing reference. It is proposed in the following notes to undertake the study of the histology of the vegetative organs, and thereafter to ascertain how far this knowledge applies to the determination of species. The following notes deal with the histology of the primary stem.

The material used, including in all 16 species and varieties, was kindly supplied from the following sources :—11 species from the Director of the Royal Botanic Garden, Kew; 8 species from the Director of the Royal Botanic Garden, Edinburgh; 2 species from Professor Trabut, Algiers; *E. Helvetica* from Professor Schroeter, Zurich; *E. altissima Helvetica* from Professor Flahault, Montpellier,—to all of whom I here tender my thanks. Material for the study of 3 species was purchased from the Botanical Supply Association. For permission to examine the living specimens in the Royal Botanic Gardens of Kew and of Edinburgh I have to thank the Directors of these Gardens.

*Œcology.*—The genus Ephedra, consisting of some 32 species, belongs to the Gnetaceæ, an order of the Gymnospermæ. The majority of the species are found in the desert parts of both the Old and New Worlds. Correlated with their physiologically dry surroundings, the plants exhibit to a very marked degree various xerophilous adaptations. The leaves in almost every species are reduced to mere scales, while the green colour of the stem shows that the photo-synthetic functions are carried on there. Further reduction of transpiration is effected through the sinking of the stomata in furrows, while each stoma lies in a deep depression of the epidermis. The tender apex is surrounded by many envelopes of leaves, being thus protected from excessive insolation. At the approach of the dry season many species lose a great number of the young branches, thereby leaving only the more mature stems to function through the dangerous period of the year. The erect broom-like habit, so characteristic of many species, exposes a minimum area to the strong light of the noonday sun, while the

position enables full advantage to be taken of the optimum light of the early and the late day.

*Tegumentary System.*—The surface of the stem of the Ephedreæ closely resembles that of an ordinary Equisetum, in possessing longitudinal ridges and furrows (Plate I., fig. 15), the former corresponding in position with hypodermal stereom strands. The cells of the epidermis are rectangular or slightly hexagonal in shape, being elongated in the direction of the stem axis. The cells at the base of the internode are not usually so much elongated as those in the middle portion of the same. The outer cell walls consist of three strata (Plate I., fig. 1); the most external is a heavily cutinised stratum, bounding a middle layer of mucilage, containing small crystals or granules of calcium oxalate, which tend to have a stratified arrangement. This layer is limited internally by a thick stratum of cellulose. The cells contain the normal cell constituents, with, in some cases, starch grains, while again the cell contents may be stained various shades of yellow. The coloration is apparently due to the presence of tannin, as the cells give a black reaction on treatment with ferric acetate. In some cases the epidermal cells are divided into two by a wall which may be parallel, or nearly so, to any of the three dimensions of the cell. Either of the daughter-cells may further divide by a wall inclined at an angle to the first division wall (Plate I., fig. 2). In some species this division occurs more frequently in the neighbourhood of a stoma, though it may also be shown in independent cells. No trace could be found of the pores recorded by STAPF as passing through the cell wall. The only suggestion of their appearance was the striation in the cellulose layer seen after treating the section with sulphuric acid and methylene blue. These striæ ended at the limit of the cellulose layer.

The epidermal cells covering the ridges are, as a rule, larger than elsewhere; while the external walls are either markedly convex outward, or bear on their outside papillæ into the base of which a blunt protoplasmic protrusion extends (Plate I., fig. 3). The roughness of the surface of the shoot is determined by the number of papillæ (Plate I., fig. 4). The core of the papilla appears to be mucilaginous, and on the addition of water it swells, bursting the cuticle with which it is covered. Owing to the similarity of these papillæ to those found in leaves, and described by HABERLANDT (1) as light-sense organs, an attempt was made to test their optical properties, GRAHAM (2). In this, methods essentially those of HABERLANDT were used. A piece of the young shoot about 1 cm. in length was divided into two. One half was then laid upon a glass slide, while the epidermis was freed from the adjacent tissues by gently scraping with a scalpel. The epidermis was now mounted upside down on a cover-glass, which was then used to roof a moist chamber about 4 mm. deep. The preparation was then placed on the stage of a microscope, extraneous light being shut out by enclosing the stage and tube in a black hood. The sub-stage iris was partly closed, when the whole field appeared darkened, with the exception of certain lighted areas corresponding in position with the papillæ (Plate I., fig. 5). Further, the image of an object, either stationary or in motion, placed before the microscope, could be clearly seen in the light

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centres. It was found to be possible to obtain photographs both of the light discs and of the images in them of objects held before the mirror (Plate I., fig. 6). The occurrence of these organs in stems which function to a great extent as leaves is almost to be expected, and the advantage of the erect light position to the desert forms of the Ephedreæ is obvious from an œcological point of view. Any movement of the stem from the normal light position will be followed by a transference of the lighted area to another portion of the cytoplasm of the back wall of the epidermal cell. This transference, accompanied as it must be by a variation in the intensity of the illumination, will act as a stimulus resulting in growth movements, whereby the former light position will be returned to.

Stomata in single or double rows occur in the furrows between the ridges. Each stoma is sunk in a compartment below the surface of the epidermis (Plate I., fig. 7). The entrance to the ante-chamber is more or less constricted by the encroachment of the walls of the four surrounding cells (Plate I., fig. 8). The encroaching wall contains a central core of mucilage, and in *E. viridis*, where the material had been treated with water, the mucilage had swollen, causing the opposite walls of the chamber to meet. This suggests an adaptation for either narrowing or closing the chamber, and thus limiting transpiration. This is the probable explanation of the closing of the stomatal chambers by resinous masses, referred to by VOLCKENS, and instanced by STAPF (3). The surface shape of the aperture depends upon the degree of encroachment of the projecting walls of the ante-chamber. The guard cells are without the usual ridges of entrance and of exit, as described by DE BARY * (4).

*The Cortex* is well developed, consisting of chlorenchyma and stereom. The chlorenchyma is differentiated into an outer palisade cortex of radially elongated cells, and an inner spongy cortex of polygonal cells, both having a well-developed aerating system, especially the latter (Plate I., fig. 9). Starch grains occur all through the cortex along with crystals of calcium oxalate, the latter being more abundant in the endocortex, where crystal sacs may occur. Calcium oxalate crystals also occur in the cell walls. In some species a very large proportion of the cortical cells contain tannin, either in the form of mucilage or in the form of small globular masses (Plate I., fig. 2). A sinuous layer of tangentially elongated, closely packed cells, containing large starch grains surrounding the stele, constitutes an endodermis. The innermost layer of the cortex abuts on to this layer at right angles.

In the stem occur typically four series of strengthening fibres. The walls are at first of condensed cellulose, colouring blue only after prolonged treatment with iodine and sulphuric acid; afterwards the walls become lignified, and are coloured red by phloroglucin and hydrochloric acid. Excluding the perimedullary stereom system, reference to which will be made later, the remaining three series of fibres are arranged on a girder principle, that is, a broad flange at either end, the hypodermal and

* The outer and inner walls of the guard cells are lignified from an early date, a condition found in many of the Coniferæ.

pericyclic stereoms, linked radially by an incomplete mesocortical web (Plate II. fig. 10). In all the specimens examined the contours of the hypodermal groups of fibres were fairly uniform, being a flange or triangle with a longer or shorter portion projecting centripetally. The mesocortical and the pericyclic groups of fibres vary considerably, in some cases inversely. The mesocortical web consists of isolated fibres or groups of fibres, usually numerically less than the hypodermal or pericyclic groups. In some cases the mesocortical groups are poorly developed, and in a few cases are almost suppressed; when this occurs the hypodermal is usually well developed. The single mesocortical fibres resemble those of Welwitschia in having calcium oxalate deposited in their external membranes (Plate II., fig. 10). This is also the case in the hypodermal fibres of *E. Helvetica*. The pericyclic stereom appears as a series of hard bast crescents or aggregates associated with the primary vascular bundles, one large or a few smaller ones to each (Plate II., fig. 11). Between adjacent crescents occasionally a series of isolated fibres occur.

A perimedullary stereom in the form of a discontinuous ring of sclerenchyma occurs in some species (Plate II., fig. 12); in others it is represented by a few isolated fibres or nests at intervals, while it may be absent altogether.

*Vascular System.*—The vascular system resembles that found in Equisetum, with these differences, that in this case the leaf-trace is paired, that it is continued in the cauline part of its course through two internodes, and that in certain species an accessory bundle accompanies each leaf-trace through part of its course, while some species show a fusion of the leaf-traces in part of their course. With these exceptions the bundles in each describe a similar course, alternating in each internode and forming vascular networks at the node. The leaves, reduced to mere scales, are situated in twos or threes at each node. In the former case the arrangement is opposite and decussate, in the latter the whorls alternate. When there are two leaves at the node, the normal shoot shows in cross section a system of six, eight, or ten collateral endarch bundles surrounding a large pith. The structure of the primary bundle is as follows (Strasburger, 5). The whole is surrounded by a parenchyma sheath, some of the cells of which may contain chlorophyll. The primary phloem consists of cambiform parenchyma elements and narrow sieve-tubes with oblique plates. The primary xylem consists of spiral elements and bordered pitted elements with parenchyma packing tissue. The bordered pitted elements include both tracheids and vasa, the latter having their end walls steeply inclined and perforated by one or two rows of slightly bordered holes (Von Mohl, 6). Between the bundles medullary rays occur, but soon the bundles are linked up by the completion of a cambium ring. Projecting from the xylem elements of the system in some species isodiametric lignified cells with reticulate thickening occur, and these at an early stage link up the adjacent bundles (Plate II., fig. 11). These cells are the first products of the activity of the cambium. Extending from the xylem to the medullary rays, as they do, they facilitate a rapid lateral distribution of crude sap to the chlorenchyma.

The leaf-trace, composed of two bundles, passes down the stem vertically through two internodes. At the third node from that of their entrance to the stem, the bundles fuse right and left with the corresponding bundles of the traces emerging at this node (Plate II., fig. 13). Thus the first internode from an apical bud which has the vascular tissue developed shows in cross section four bundles, while in the second and subsequent internodes eight bundles are seen, two pairs of large bundles forming the traces of the leaves at the second node above, alternating with two pairs of small traces supplying the leaves at the first node above. A similar system is found in those species which have three leaves at each node; the extra trace pairs in this case bring the number of bundles in each internode up to twelve (Plate II., fig. 15). In the internode of species whose phyllotaxis changes from two to three, the internode succeeding the node at which the alterations occur shows ten bundles.

Immediately above each node occurs a region of two or three layers of compressed living cells with thick cellulose walls forming a dehiscence layer (Plate III., fig. 16). This layer, with in some cases a small area of meristematic tissue in the node itself, arises from the remains of the meristematic tissue from which elongation of the internode took place (Plate III., fig. 17). The layer partially cuts through the vascular tissues, the connection of the xylem elements being kept up by means of short reticulate tracheids. In the cortex the layer also appears, and there is a slight ring-like constriction of the surface of the stem corresponding to it in position. The epidermal cells over the constriction are nearly isodiametric. Owing to the stoppage of the stereom systems on approaching this region, the internode is very brittle and readily breaks across at this point. While passing through the area of meristematic tissue the vascular bundles lose their accompanying lateral lignified flanges.

At the node the stelar elements are concentrated into two vascular crescents, through the intercalation of linking tracheids. Spaces are left between the crescents corresponding with the position of the leaves at the node (Plate III., fig. 18). Each crescent is composed of the trace bundles from the leaf at the node above, flanked by a trace bundle from each leaf at the second node above (see Plate II., fig. 13). The leaf-traces of the leaves at the node in question link on to the crescent before passing out to the leaves at the node. Just below the emergence of these leaf-traces the vascular supply for the axillary bud originates as a twig from each leaf-trace (see fig. 13).

*Lateral Branch.*—Each of the bud-traces bifurcates to form the leaf-traces of the first pair of leaves on the side branch. At the first node of the lateral branch vascular crescents are formed. The traces from the leaves at the two next higher nodes unite in pairs during their course in the second internode of the branch. Hence, apparently only two instead of the normal four bundles take part in the formation of each vascular crescent at the first node (Plate III., fig. 19).

*Accessory Bundles* (STRASBURGER'S "complementary bundles" (7) ).—Originating from the centre of each vascular crescent, an accessory bundle accompanies each leaf-trace pair in the upper half of its course (Plate II., fig. 14). So far, only in one instance

has the accessory bundle been found accompanying the leaf-trace in the lower half of its course. The accessory bundle, on reaching the node above that at which it originates, bifurcates at the level of the vascular crescents. Each half of the accessory then passes out as an additional pair of traces to the axillary bud (Plate III., fig. 20). The bud supply is hence augmented by two traces; thus in cross section with the first shortened internode of the side branch six bundles appear arranged, two adaxially and four abaxially. Before the bud-traces pass out to the first leaves of the side branch, the accessory bud-traces fuse with them (see fig. 20). Thus the accessory bud supply is shared by the two leaves. In *E. altissima*, *E. intermedia* from Kew, in *E. altissima* from Algiers and from Montpellier, as also in *E. distachya*, *elegantissima*, *lanceolata* from Edinburgh, the leaves of the first node of the lateral branch are in many cases suppressed. This feature has been occasionally observed in other species. In correlation with the absence of leaves, no splitting occurs in the bud supply, while the accessory, when present, ends in the vascular crescents of the main axis.

*Concrescent Bundles.*—This system is derived from the eight-bundle or normal type by the fusion of the adjacent leaf-traces of the opposite leaf-trace pairs in the second half of their course (Plate III., fig. 21, i.). At the end of its course the concrescent trace splits and the two portions link on right and left with the traces on either side (fig. 21, ii.). Thus an incomplete ring is formed, interrupted only between the non-concrescent leaf-traces. At the node through the formation of the girdle of tracheids these non-concrescent traces become joined up (fig. 21, iii.). Thus, through the ultimate splitting of the concrescent bundle vascular crescents are formed composed of the same constituents as the vascular crescents in the normal type (fig. 21, iv.).

Occasionally another type of concrescence occurs through fusion of the leaf-traces in the first half of their course. Exceptionally, concrescence takes place in all the leaf-traces, and the number of the bundles is reduced to four. The leaf-traces in the leaves appear to be very close together in this last case.

When there are three leaves at the node the typical vascular system is still retained. If the leaf-traces be accompanied by an accessory, the number of bundles seen in section is fifteen (Plate III., fig. 22); while if concrescence occur in the latter half of the course of the bundle, the number of bundles seen is nine (Plate III., fig. 23).

These variations due to intercalation and concrescence of bundles may take place at different levels in the course of the trace, and need not be synchronous on the two sides. Hence in different internodes of the same individual four, five, six, seven, eight, nine, and ten bundles may be met with. Similar variations occur in those species which have three leaves at the node.

The *Pith* consists of large and small cells, whose walls from an early stage are lignified, except around the intercellular spaces. Lignification is centripetal, being found in the fourth internode of *E. fragilis*, v. *campylopoda*. The perimedullary stereom (Plate II., fig. 12) has already been noticed. Cells containing tannin mucilage occur in many species, though they may be entirely absent from others (Plate III.,

fig. 22). Certain of the pith cells in the neighbourhood of the protoxylems show greenish-coloured contents, which seem to be chlorophyll. The cells of the pith have pitting on all their walls, especially on the end walls (Plate III., fig. 23).

*Meristematic Tissues.*—The stem apex, enclosed in several whorls of leaves, consists of a small conically-shaped mass of tissue. According to DINGLER (8), growth is from a tetrahedral apical cell. In all the material examined the meristem has been found to be stratified. Different records in regard to the nature of the apex have, however, been made, and DE BARY (9) mentions that both forms of apex occur in the same species. In the first internode after the apical the stelar elements have begun to differentiate, while in the second internode they are well developed. In this internode elongation of the stem has set in, but is more pronounced in the succeeding two or three internodes. At first the whole internode is meristematic (Plate III., fig. 17), but later elongation comes from a meristem situated at the base of the internode. This basal meristem remains functional for some considerable time, eventually passing over into permanent tissue, with the exception of a layer of from two to three cells in thickness, situated just above the node. This layer functions as a dehiscence layer (Plate III., fig. 16).

## PART II.—HISTOLOGY APPLIED TO THE DETERMINATION OF SPECIES.

Considerable attention has recently been paid to the use of the internal structure of the vegetative organs of plants in the diagnosis of orders, genera, and species. The genus Ephedra, consisting as it does of a uniform œcological group of species, seems to furnish a fair test of the value of such diagnostic characters. In his paper on Gnetaceæ and Coniferæ, BERTRAND (10) was of opinion that the histological features of stem and leaf were insufficient, and not thoroughly trustworthy for specific distinctions. This opinion is also held by Dr STAPF in his monograph, "Die Gattung der Ephedreæ," in which he constantly emphasises the extreme variability of the histology of the vegetative organs. While the tendency to variation in the histology is admitted, it has yet been possible, as a result of the above-mentioned notes, to divide the genus into subgeneric groups. Further, the additional evidence furnished from the internal structure, when taken with the ordinary external morphological characters, greatly facilitates diagnosis. The idea with which this part of the work was undertaken was to work from some definite level, and thereafter to include such other features from other parts of the stem as might seem to be of value. The second elongated internode from an apical bud was taken to start with, as being the youngest in which the complete primary stelar structure is attained. A general division of the group can be made, basing the evidence on the vascular supply of this internode. The number of bundles is very constant in some species (eight in *foliata*, *Helvetica*, *procera*, *distachya*; ten in *viridis*); while in a few there is a slight tendency to vary (*nebrodensis* and *gerardiana*), and in even fewer variations actually occur (*trifurca*). These variations are never of such an extent that they interfere with the value of the classification, for

they never interfere with the average number of bundles, and hence the type can always be determined. Two other important features for distinction of species are mentioned by FRITSCH (11). These are the occurrence of isolated groups of sclerenchyma in pith and cortex, and the distribution of secretory organs. Both of these can be applied to the genus Ephedra. The development of the mesocortical stereom web, as already mentioned, is much better in some species than in others. A division can, therefore, be made into species which have a well-developed mesocortical stereom (*foliata*, *distachya*, *viridis*), and those in which the stereom is poorly developed (*trifurca*, *fragilis*, *Helvetica*, *procera*). Again, the extent to which the perimedullary stereom is developed furnishes a basis for another threefold division. The perimedullary stereom is represented in two stages of development—as a discontinuous ring (*nebrodensis*), as a series of isolated fibres (*trifurca*, *foliata*, *distachya*, *viridis*), or as absent altogether (*fragilis*, *Helvetica*, *gerardiana*, *procera*). The presence of tannin sacs in the pith of many species (*Helvetica*, *distachya*, *procera*) furnishes another basis for division.

In determining the value of varieties, histology plays an important part. Thus *E. nebrodensis* differs from *E. procera*, not only in the former having a roughened epidermis while the latter is smooth, but *E. nebrodensis* has ten vascular bundles, while *E. procera* has only eight. A striking instance occurred in regard to three specimens received from Edinburgh. The names borne by the plants were apparently synonyms for *E. altissima*. Their identity was established by a study of their histology, and by a subsequent examination of the plants with regard to external morphology the identity was confirmed.

TABLE OF SPECIFIC DISTINCTIONS, BASED ON THE CHARACTER OF THE VASCULAR SYSTEM OF THE SECOND INTERNODE, STEREOM GROUPS, AND PITH.

1. *E. trifurca* (TORR). Primary bundles, 12 or 15. Mesocortical stereom web poorly developed. Perimedullary stereom isolated fibres. No pith tannin sacs.
2. *E. foliata* (C. A. MEYER). Primary bundles, 8. Mesocortical stereom web well developed. Perimedullary stereom isolated fibres.
3. *E. fragilis* (DESF.). Primary bundles, 8. Mesocortical web poorly developed. Perimedullary stereom absent. No pith tannin sacs.
4. *E. Helvetica* (C. A. MEYER). Primary bundles, 8. Mesocortical stereom web poorly developed. Perimedullary stereom absent. Pith tannin sacs.
5. *E. distachya* (LIN.). Primary bundles, 8. Mesocortical stereom web well developed. Perimedullary stereom isolated fibres. Pith tannin sacs.
6. *E. gerardiana* (WALL). Primary bundles, 10. Perimedullary stereom absent. Pith tannin sacs.
7. *E. nebrodensis* (TINEO). Primary bundles, 10 or 15. Perimedullary stereom discontinuous ring. No pith tannin sacs.
8. *E. procera* (C. A. MEYER). Primary bundles, 8. Mesocortical stereom web poorly developed. Perimedullary stereom absent. No pith tannin sacs.
9. *E. viridis* (COVILLE). Primary bundles, 10. Mesocortical stereom web well developed. Perimedullary stereom isolated fibres. Pith tannin sacs.

In conclusion, I wish to thank Mr R. A. Robertson, at whose suggestion the work was undertaken, for his great help throughout its course.

## DESCRIPTION OF PLATES.

### Plate I.

Fig. 1. Transverse section of *E. Helvetica*, showing epidermal cells with thickened external wall. (*a*) Cuticle; (*b*) calcium oxalate layer; (*c*) cellulose stratum. × 360.

Fig. 2. Transverse section of *E. fragilis* (Algiers). (*a*) Division of epidermal cell into two; (*b*) division of one of the daughter-cells by a wall at right angles to the first division wall; (*c*) cortical tannin sacs. ×-160.

Fig. 3. Transverse section of *E. viridis*, showing large epidermal cells over ridge, one having a papilla on the external wall. (*a*) Cuticle; (*b*) calcium oxalate layer; (*c*) cellulose stratum. × 360.

Fig. 4. Surface view of *E. viridis*, showing papillæ and stomata in alternating rows. × 42.

Fig. 5. Photomicrograph of preparation of the epidermis of *E. altissima*, showing position of light spots. × 160.

Fig. 6. Photomicrograph as above of *E. altissima*, showing image of St Andrew's cross in each light spot. × 160.

Fig. 7. Transverse section of *E. nebrodensis*, showing sunk stoma, guard cells, respiratory chamber, ante-chamber. (*a*) Mucilaginous core of wall of cells forming ante-chamber. × 360.

Fig. 8. Longitudinal section of *E. distachya*, showing stoma, respiratory chamber, ante-chamber. (*a*) Mucilage core of cell wall. × 360.

Fig. 9. Transverse section of *E. nebrodensis*, showing hypodermal stereom, and differentiation of cortex into palisade and spongy cortical cells containing starch grains and crystals of calcium oxalate. × 160.

### Plate II.

Fig. 10. Transverse section of *E. distachya*, showing stereom systems well developed. (*a*) Welwitschia-like fibres; (*b*) division of epidermal cell. × 160.

Fig. 11. Transverse section of *E. distachya*, showing pericyclic stereom crescent and vascular flange projecting from xylem. (*a*) Pericyclic stereom crescent; (*b*) vascular flange. × 160.

Fig. 12. Transverse section of *E. nebrodensis*, showing perimedullary stereom (*a*). × 160.

Fig. 13. Diagram of eight or normal bundle system, showing the entrance of the trace at $a^{i}$, the parallel course of the bundles, the behaviour of the trace at the first node ($a^{ii}$), the continuation through a second internode and the linking on of the traces to the bundles passing out at the third node ($a^{iii}$). Vascular crescents (*a*) with their component parts are diagrammatically indicated. The bud-trace (*b*) is indicated in position below the passing out of the trace at $a^{i}$. The splitting of the bud-trace is indicated.

Fig. 14. Diagram of the ten or accessory bundle system. Explanation as in last. The accessory (*c*) is indicated splitting in the region of the vascular crescent at $a^{i}$, where it passes out to form an extra pair of bud-traces.

Fig. 15. Transverse section of *E. trifurca*, showing twelve bundles due to the presence of three leaves at the node. × 42.

### Plate III.

Fig. 16. Longitudinal section of *E. nebrodensis*, showing dehiscence layer. × 42.

Fig. 17. Longitudinal section of apex of *E. foliata*, showing development of young internode. × 42.

Fig. 18. Transverse section of *E. fragilis*, v. *campylopoda*, showing vascular crescents with accessory splitting in between. × 42.

Fig. 19. Diagram of junction of lateral branch with main stem, showing the bifurcation of the bud-trace (*b*) and its course into the leaves; the fusion of the traces of the higher leaves of the lateral branch before their arrival at the first node (*a*), thereby making the crescent have the appearance of being made up of only two bundles.

Fig. 20. Diagram of the junction of lateral branch in the accessory system. The main features are as above, while the splitting of the accessory bundle to augment the bud-supply is indicated (*c*); also the fusion

of the twigs of the accessory with the normal bud-trace before they pass to the leaves is shown (*f*). The accessory is represented as being absent from the first two internodes of the side branch.

Fig. 21. Diagram of the behaviour of the concrescent bundle at the end of its course. (i.) represents the six bundles after the disappearance of the lateral flanges; (ii.) represents the concrescent bundle linking on to the traces on either side; (iii.) represents the concrescent bundle as split, while the non-concrescent bundles have become united by the formation of intercalary tracheids; (iv.) represents the true vascular crescents formed equally of the traces from the first node above, flanked on either side by half the concrescent bundle.

Fig. 22. Transverse section of *E. trifurca*, showing fifteen bundles due to three leaves at the node, each leaf-trace pair being accompanied by an accessory. × 42.

Fig. 23. Transverse section of *E. elegantissima*, showing nine bundles due to three leaves at each node, the leaf-traces being concrescent in the second half of their course. × 42.

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R. J. D. Graham: "Histology of the Ephedreæ."—Plate I.

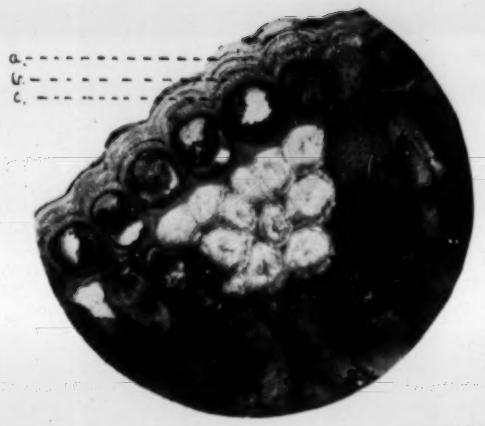



Fig. 1.

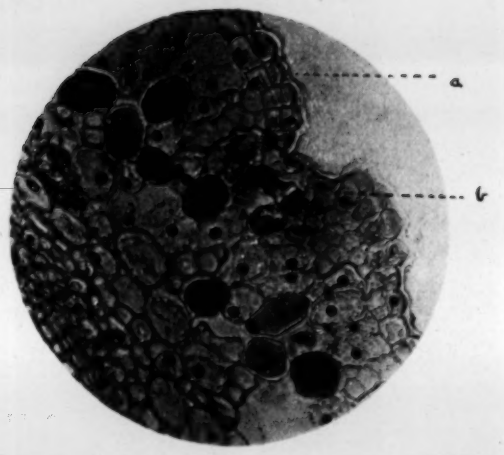



Fig. 2.

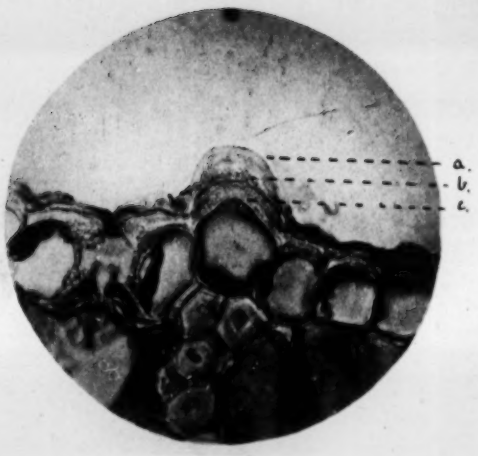
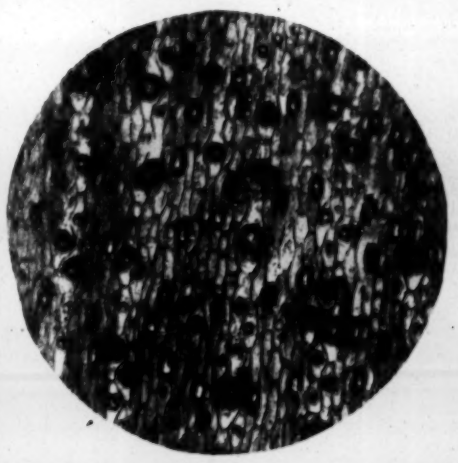



Fig. 3.



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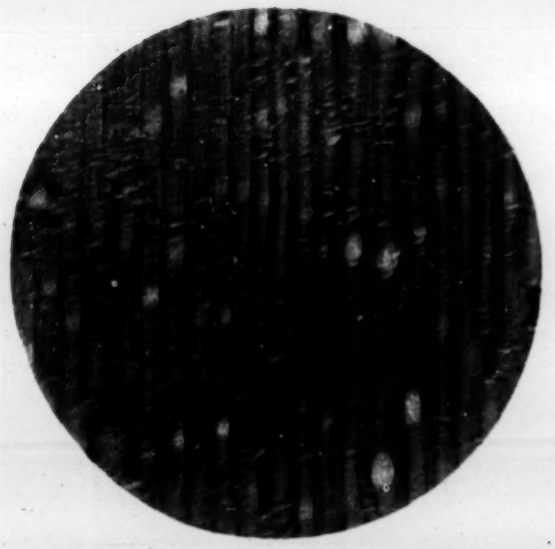

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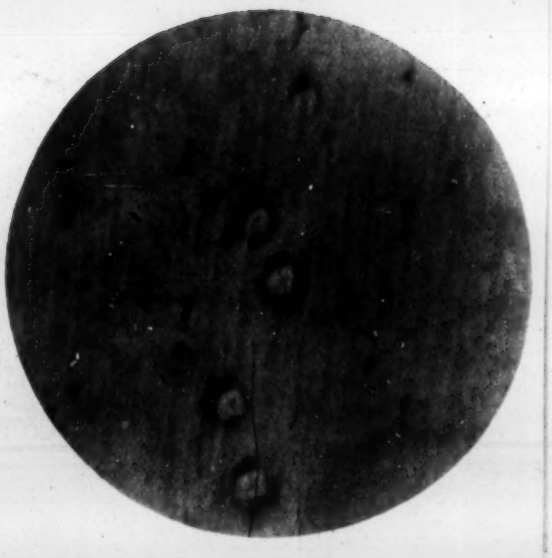

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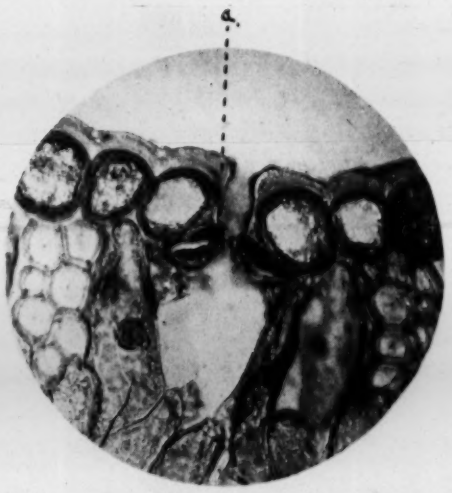



Fig. 7.

Fig. 8.

Fig. 9.

R. J. D. GRAHAM: "Histology of the Ephedreæ."—PLATE II.

FIG. 10.

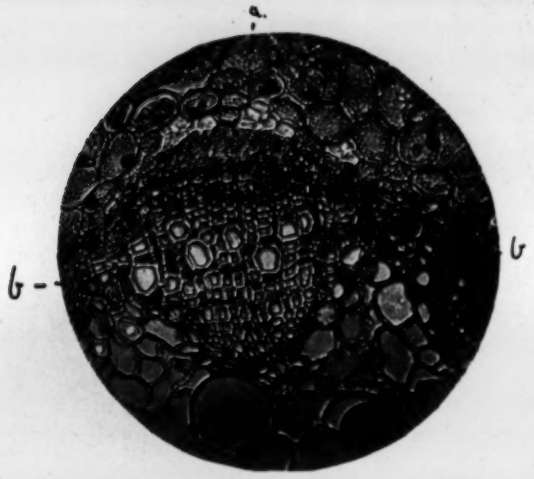



FIG. 11.

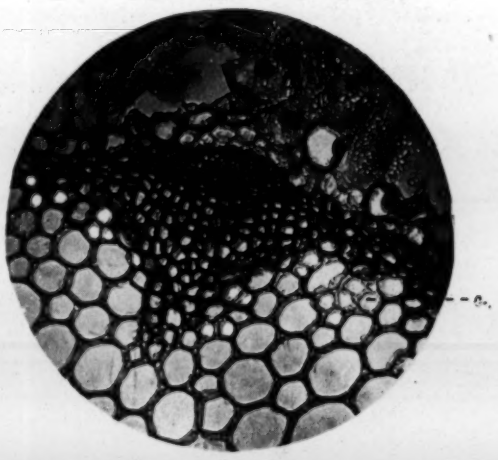



FIG. 12.

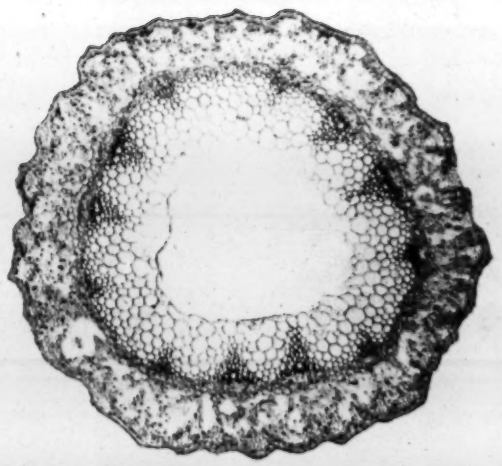


FIG. 15.

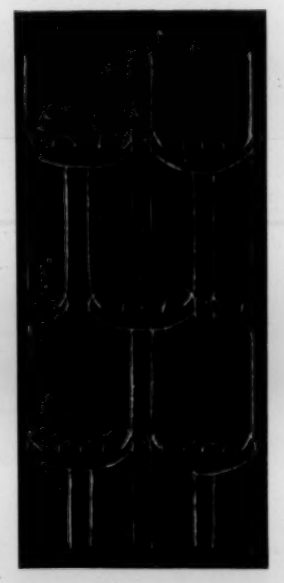


FIG. 13.

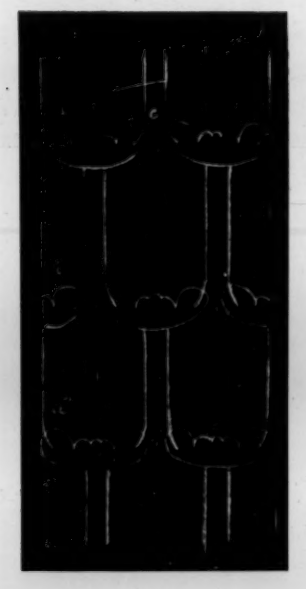


FIG. 14.

R. J. D. GRAHAM: "Histology of the Ephedreæ."—PLATE III.

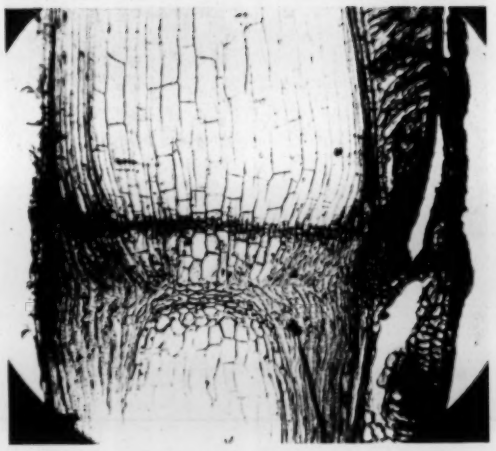


FIG. 16.

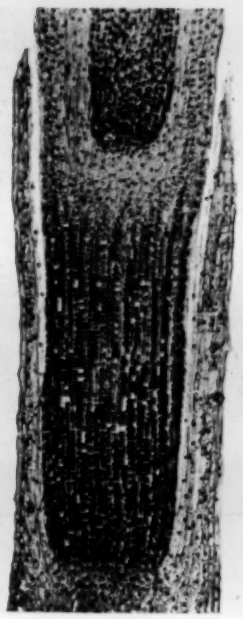


FIG. 17.

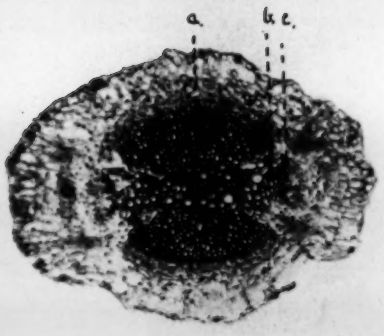



FIG. 18.

i.

ii.

iii.

iv.

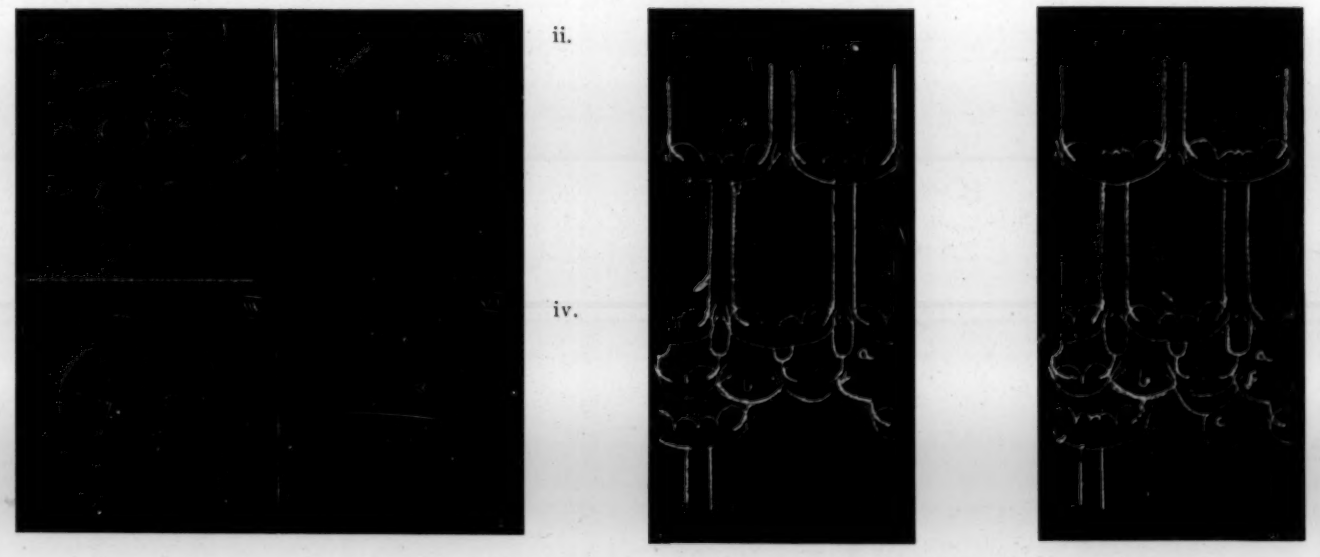


FIG. 21.



FIG. 19.



FIG. 20.

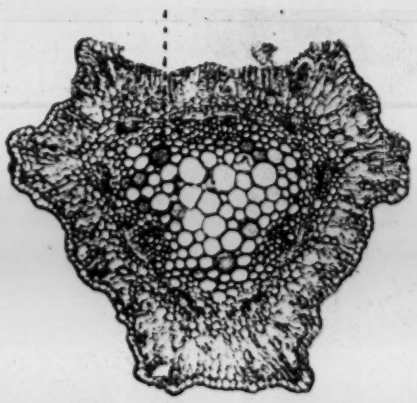


FIG. 23.

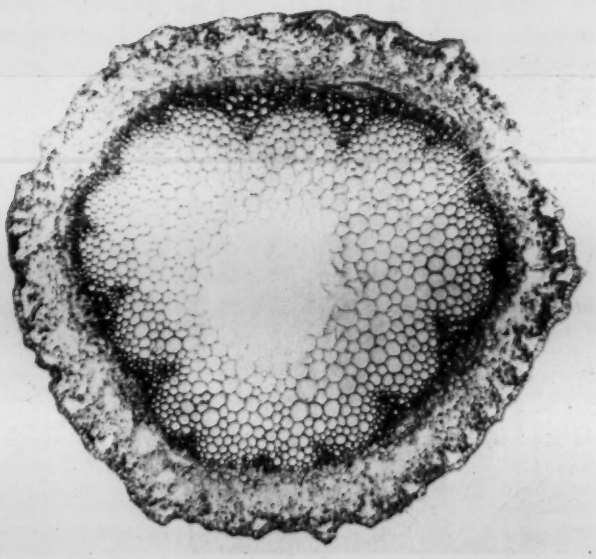


FIG. 22.

# IX.—On the Fossil Osmundaceæ. Part II.

By **R. Kidston**, F.R.S. L. & E., F.G.S., Foreign Mem. K. Mineral. Gesell. zu St Petersburg; and **D. T. Gwynne-Vaughan**, M.A., F.L.S., Lecturer in Botany, Birkbeck College, London.

(Plates I.–IV.)

(MS. received January 6, 1908. Read same date. Issued separately March 27, 1908.)

## PART II.*

## **Zalesskya gracilis**, Eichwald, sp., and **Zalesskya diploxylon**, Kidston and Gwynne-Vaughan, n.sp.

While the first part of this paper was in course of preparation a search was made through various palæobotanical publications in the hope of meeting with records of Osmundaceous fossils that had hitherto escaped recognition as such. In so doing our attention was at once attracted by the descriptions and figures given by Eichwald in his *Lethæa Rossica* of some very fine fossils which were held by him to represent the stems of arborescent ferns. Those in which we were particularly interested were *Chelepteris gracilis*, Eichwald,† *Sphallopteris Schlechtendalii*, Eichwald,‡ *Bathypteris rhomboidea*, Eichwald,§ sp., and *Anomorrhæa Fischeri*, Eichwald.‖ The figures and descriptions of these plants were quite inadequate for the determination of their true affinities; but it must be remembered that at the time when these descriptions were written by Eichwald many structural characters which are now regarded as of paramount importance in determining affinities were not recognised as such, even by botanists. To enable us if possible to clear up these difficulties, we wrote to Mons. Michel Zalessky, geologist on the staff of the Comité géologique, St Petersburg, asking if the types of these specimens were known to be in existence, and if any preparations had been made from them suitable for microscopical examination.

On receiving our letter Mons. M. Zalessky instituted a most laborious search in several museums, and was eventually successful in finding the types of the four genera already mentioned in the Museum of the Institute of Mines, St Petersburg. No sections for microscopical examination had ever been prepared from any of the stems, though the microscopical structure of the petiole base of *Sphallopteris Schlechtendalii* had been imperfectly described by Eichwald,¶ and that of *Bathypteris rhomboidalis* by Schmalhausen.**

* Part I., *Trans. Roy. Soc. Edin.*, vol. xlv., part iii. (No. 27), pp. 759–780, pls. i.–vi., 1907.

† *Lethæa Rossica*, vol. i., p. 98, pl. iii., figs. 4, 5, and 6, 1860.

‡ *Ibid.*, vol. i., p. 93, pl. iii. figs. 1–2, pl. xx. figs. 2–5.

§ *Ibid.*, vol. i., p. 96, pl. iv. figs. 1–2 (= *Tubicaulis rhomboidalis*, Kutorga (*pars*), *Verhandl. d. Miner. Gesell. zu St Petersburg*, pl. i. fig. 6, 1844).

‖ *Ibid.*, vol. i., p. 102, pl. iv. figs. 3–4.

¶ *Ibid.*, pl. xx. figs. 2–5.

** "Die Pflanzenreste d. Artinskischen und Permischen Ablagerungen," etc., *Mém. du Comité géol.* (St Petersburg), vol. ii., No. 4, pp. 9 and 36, pl. iii. figs. 6–7, 1887.

The references to the internal structure of *Chelopteris gracilis* and *Sphallopteris Schlechtendalii*, embodied in EICHWALD's descriptions of these species, only refer to characters observable by the hand-lens.

With the object, therefore, of submitting the stems of *Chelepteris*, *Sphallopteris*, *Anomorrhœa*, and *Bathypteris* to a careful microscopical examination, the Director of the Comité géologique had portions cut from each of these stems, and most generously presented them to us for examination; and we take this opportunity of expressing our indebtedness and sincere thanks to Mons. TH. TSCHERNYSCHEW for supplying us with the necessary material for our examination of these genera, and to Mons. MICHEL ZALESSKY for the willing labour bestowed on searching for the specimens. To Mons. ZALESSKY we are further indebted for excellent photographs of the external surface of the specimens, which were taken by Mons. KOCH.

Although in the present paper only *Chelepteris gracilis*, Eichwald (for which, for reasons stated later, we propose the genus *Zalesskya*), and a new species of the same genus are described, it is desirable, before proceeding further, to consider the relationship and distinctive characters of *Chelepteris*, *Sphallopteris*, *Bathypteris*, and *Anomorrhœa*, all of which are placed by CORDA* and EICHWALD† in the *Protopterideæ*, the chief character of which is the horse-shoe shaped vascular bundle of the petioles.

## Chelepteris, Corda.

1845. *Chelepteris*, Corda, *Flora d. Vorwelt*, p. 76.

*Stem arborescent, round, erect; exposed cicatrices of leaves supported on elevated cushions, spirally arranged and ornamented with adventitious rootlets. Cicatrices oblong or ovate, with a single median crescent-shaped vascular bundle.*

This genus was founded for the reception of three fern stems which were described by SCHIMPER and MOUGEOT under the names of *Caulopteris Voltzi*,‡ *Caulopteris micropeltis*,§ and *Caulopteris Lesangeana*.‖

EICHWALD, who adopted this genus for his *Chelepteris gracilis*, thus describes it:—

## Chelepteris (Corda), Eichwald.

1860. *Chelepteris*, Eichwald, *Lethæa Rossica*, vol. i., p. 98.

*Stem arborescent, straight, cylindrical, formed of petiole bases, very close and cylindrical, disposed vertically in spiral series and showing on their fractured end a single semilunar vascular bundle with rarely occurring adventitious roots in the interstices of the petiole bases; the ligneous body (stele) is complete and its walls are stout.*

* *Flora d. Vorwelt*, p. 75.
† *Loc. cit.*, p. 92.
‡ *Monog. d. plantes foss. du grès bigarré de la chaine des Vosges*, p. 65, pl. xxx., pl. xxxi. figs. 1–2, 1844.
§ *Ibid.*, p. 67, pl. xxxi. fig. 3.
‖ *Ibid.*, p. 67, pl. xxxii.

In addition to a few structural features added by EICHWALD, the leaves are said to be very close.

## Sphallopteris, Corda (emend.).

1845. *Sphalmopteris*, Corda, *Flora der Vorwelt*, p. 76.

*Stem arborescent, round, external cushions elevated, spirally arranged* (5/8). *Cicatrices showing the impression of a central depressed simple horse-shoe shaped vascular bundle.*

The type of CORDA's *Sphallopteris* is the stem which BRONGNIART referred to his *Anomopteris Mougeotii*,* and which is figured in the *Hist. d. végét. foss.*, vol. i., pl. lxxx.†

BRONGNIART believed this fern stem to have borne the fronds he named *Anomopteris Mougeotii*,‡ on account of their large size and being found in the same bed as the stem. They were not, however, found in organic union, hence the uncertainty of the stem and fronds belonging to the same species; and this consideration induced CORDA to place the stem in a separate genus.

It is very interesting to notice that traces of a semilunar vascular bundle were seen on some of the broken-over petioles, which are compared to those of *Osmunda regalis* by BRONGNIART.

EICHWALD thus describes the genus:—

## Sphallopteris (Corda), Eichwald (emend.).

1860. *Sphallopteris*, Eichwald, *Lethæa Rossica*, vol. i., p. 92.

*The exterior of the stem is composed of a cortex formed of adventitious rootlets and petiole bases or cushions disposed in regular spiral series, and which are very prominent and very large, and show in transverse section cicatrices in the form of a horse-shoe in the middle or on their surfaces.*

"The cushions are triangular or almost rhomboidal, the two lateral edges are always acute, the inferior or anterior margin is also acute, but the superior or posterior margin is rounded, rarely pointed, and is not raised up above the surface of the stem, as the inferior; it loses itself likewise in the leaf; the horse-shoe shaped vascular bundle has its two extremities bent in as a hook.

"The interpulvinar area is entirely riddled with vascular bundles, which form sometimes vertical rows, or which are sometimes disposed horizontally, leaving large furrows as the traces of their former existence.

"The woody body (*cylindrus ligneus*) is small, narrow, and occupies the axis of the stem; the vascular bundles which compose it diverge in all directions and ascend obliquely" (the leaf-traces).

* "Essai d'une Flore du grès bigarré," *Ann. d. Sc. Nat.*, Dec. 1828, p. 4.
† P. 261, 1831 or 1832.
‡ *Loc. cit.*, pls. lxxix. and lxxxi.

Eichwald, believing that his stem was generically identical with that described by Brongniart, and for which Corda founded the genus *Sphallopteris*, adds to the original characters some which are derived from the internal structure of the stem.

One of the chief distinctive differences which separates *Chelepteris* from *Sphallopteris*, as pointed out by Eichwald, is the smaller vascular axis of the latter when compared with that of the former.

## Bathypteris, Eichwald.

1860. *Bathypteris*, Eichwald, *Lethæa Rossica*, vol. i., p. 96.]

*Stem large, simple, almost cylindrical, swollen at the middle, and contracted towards the extremities; the surface is composed of contiguous petiolar bases, discs (=broken-over surface of petioles) much sunk in, almost round or somewhat squared, provided in the centre with a small semicircular cicatrice; the margins of the petiole bases only are prominent and riddled with holes or canals arising from the adventitious roots; the elongated leaves, closely placed beside each other, are fixed at the upper extremity of the stem.*

This genus is said to differ from *Chelepteris* and *Sphallopteris* in the petiole bases being scarcely visible at the surface of the stem, whereas in *Chelepteris* and *Sphallopteris* the stems possess prominent petiole bases. It will be seen as we proceed that this character depends on the state of preservation of the specimens. The stele of *Bathypteris* was not preserved.

## Anomorrhœa, Eichwald.

1860. *Anomorrhœa*, Eichwald, *Lethæa Rossica*, vol. i., p. 102.

*Stem fairly large and composed of the bases of almost rhomboidal-tubular petioles which are provided with many layers, ascending obliquely and placed quincuncially. They enlarge insensibly towards the extremity and are provided with a semicircular vascular bundle, sometimes in the form of a horse-shoe, of which the centre is hollow; the interpetiolar interstices have no adventitious roots, by which the genus is principally distinguished from the genera mentioned above.**

The stele was not preserved.

Eichwald was mistaken in supposing that *Anomorrhœa* did not possess adventitious roots, for sections of the specimen show them to be present as in all the other three genera to which reference has been made.

These four genera have been differently regarded by subsequent writers, but it must be borne in mind that probably all those authors who have referred to them had only the descriptions and figures for their guidance, for it is certain that no microscopical preparations were made from the specimens at the time they wrote, and it is also further highly probable that they were unable to examine the original types.

* The genera referred to by Eichwald are *Sphallopteris*, *Bathypteris*, *Chelepteris*, and *Desmia*.

Brongniart proposes for the fern stem which was first described by Eichwald under the name of *Anomopteris Schlechtendali*,* and subsequently placed by him in *Sphallopteris*, Corda, the new genus *Thamnopteris*,† on the ground that Eichwald's stem was not generically similar to the *Anomopteris Mougeotii*‡ which Corda had made the type of his genus *Sphalmopteris* ( = *Sphallopteris*, Eichwald).

Brongniart says in regard to his genus *Thamnopteris*: "I place under this name a frutescent erect fern stem, but with persistent petioles arranged around a very slender stem, which M. Eichwald designates under the name of *Anomopteris Schlechtendali*, because it appeared to him to offer some analogy with the stem which I have referred to *Anomopteris Mougeotii*;§ but this latter differs notably in its very slender stem surrounded by very numerous slender petioles, and which have evidently been persistent as those of our herbaceous ferns with ascending stems." ‖

We have not seen the specimen of *Sphallopteris Schlechtendalii* to which Brongniart refers, but, judging from the specimen of *Sphallopteris Schlechtendalii* which Eichwald gives on Pl. III., fig. 2, of the *Lethæa Rossica*, one would scarcely be inclined to include it in the same genus as *Anomopteris Mougeotii*, and in our future treatment of this fossil we shall adopt the name of *Thamnopteris Schlechtendali* for this stem.

There are other considerations which advocate this course, and one of these is that a microscopical examination of the specimen of the *Thamnopteris Schlechtendali* figured by Eichwald in the *Lethæa Rossica* reveals the fact that the true outer surface of the stock is not preserved, but the stem was surrounded by a thick mantle of concrescent leaf-bases, and an unknown thickness of these concrescent leaf-bases has been removed from the stem. Probably the true appearance of the outer surface of the stock would be a felted mass of rootlets in which the remains of the petioles were embedded. In fact, this specimen and those we have examined of *Zalesskya* (*Chelepteris*, Eichwald *non* Corda), *Anomopteris*, and *Bathypteris* are all more or less incomplete or even partially decorticated as in *Zalesskya*, and none of them show the true outer surface of the stock, and they might well be described as all representing a "*Knorria*" condition. Therefore, if the figure given by Brongniart as *Anomopteris Mougeotii* shows its true outer surface (which it may do), a comparison has been made between structures which hold different positions in the stock.

But a more weighty reason for the rejection of the genus *Sphallopteris* for Eichwald's plant is found in the circumstance that the structure of the type of the genus *Sphallopteris* (*Anomopteris Mougeotii*, Brongniart) is not known, and there is no warrant for inferring that it was similar to that of Eichwald's specimen. All that is known of the structure of *Anomopteris Mougeotii* is that the petioles seem to possess semilunar vascular bundles "as in the petiole of *Osmunda regalis*," but this

* Eichwald, *Urweit Russlands*, Heft ii., p. 180, pl. iv., figs. 3–5.
† Brongniart, *Tableau d. genres d. végét. foss.*, p. 35, 1849.
‡ Brongniart, *Hist. d. végét. foss.*, vol. i., pl. lxxx.
§ The *Cottæ Mougeottii* of Schimper and Mougeot, *Plantes foss. du grès bigarré*, p. 69, pl. xxxiii.
‖ *Tableau d. genres d. végét. foss.*, p. 35.

character is of too general occurrence to be accepted as indicating generic identity between the fern stems in question. The genus *Thamnopteris*, as it will be employed by us, when we come to describe the specimen in detail, will be one which derives its essential characters from the anatomy of the stem. We take this liberty of altering the generic characters on the strength of the fact that the stem we hope to describe, though not actually the individual to which BRONGNIART's remarks refer, is one of two which were figured and described by EICHWALD as belonging to his *Sphallopteris Schlechtendalii*.

It is similar considerations which have prompted us to remove the *Chelepteris gracilis*, Eichwald, from that genus and to place it in the new genus *Zalesskya*. This stem has not only lost its mantle of leaf-bases, but is also partially decorticated, so its outer surface is unknown. The whole of the characters of the genus *Chelepteris*, Corda, are derived from external features, and possibly the specimens placed in *Chelepteris* by CORDA may show their outer surface; but be this as it may, the genus *Zalesskya* is founded on characters derived entirely from its internal organisation—an organisation which one has no right to infer was possessed by the original types of the genus *Chelepteris*.

It is difficult and probably useless to attempt to define the relationship of the plants placed in *Chelepteris*, Corda, to the *Chelepteris* (*Zalesskya*) *gracilis* of EICHWALD; but we are of opinion that they are probably generically distinct, though it is impossible to determine this point satisfactorily.

The genera *Chelepteris*, Corda (*non* Eichwald), and *Sphallopteris*, Corda (emend.), are placed by BRONGNIART alongside of *Protopteris*, which is compared with the *Dicksoniæ*, though he points out that the same type of leaf-trace occurs in the *Osmundaceæ* and other ferns.

Though the genus *Protopteris*, Presl,* may be Cyatheaceous, we are clearly of opinion that the fern stems described by EICHWALD under the names of *Chelepteris* and *Sphallopteris* (without expressing any opinion on the fossils placed in these genera by CORDA) are Osmundaceous, and, along with *Zalesskya* and *Anomorrhœa*, must be removed from the *Protopterideæ*.

SCHIMPER, in his *Traité d. paléont. végét.*,† treats *Thamnopteris*, *Anomorrhœa*, *Chelepteris*, and *Bathypteris* as distinct genera, but in Zittel's *Handbuch d. Palaeontologie*‡ he unites *Anomorrhœa* and *Bathypteris* with *Thamnopteris*, remarking that there are no grounds for placing these fern stems in different genera as has been done, as the outer surfaces of all show the same characters; and had not one the structure of the specimens to direct them, this appears to us as the wisest way of treating the fossils, though, as will be seen later on, we still keep these genera separate, but from an altogether different class of characters than those observable on their outer surfaces.

We have thought it necessary to give this review of the literature of the subject, to show the opinions held by the various botanists who have written about these fossil fern

* PRESL in *Sternberg. Vers.*, vol. ii., fasc. vii.–viii., p. 169, 1838.
† Vol. i., pp. 701–3, 1869.
‡ SCHIMPER in Zittel, *Handb. d. Palaeont.*, II. Abth., Palaeophytologie, p. 145, 1879.

stems; but it must be remembered that probably none of these writers have had the opportunity of examining the specimens, and the published descriptions are quite inadequate to enable one to give a true interpretation of their systematic position.

As already stated, for the *Chelepteris gracilis*, Eichwald, we have been compelled to form a new genus, and separate it from those species originally placed in *Chelepteris* by CORDA; but as the other three genera, *Thamnopteris*, *Anomorrhœa*, and *Bathypteris*, only contain the type specimens, and these are the specimens investigated in this and the succeeding paper, we are fortunately enabled to retain the old names, though the characters on which we now define these genera are entirely derived from their internal organisation.

Our specimens of *Zalesskya*, *Thamnopteris*, *Anomorrhœa*, and *Bathypteris* are from the Upper Permian of the Oural, and their geological position is seen in the annexed table, which has been kindly communicated to us by Mons. ZALESSKY :*—

| D'après Lapparent. | | Division du permien et permo-houiller en Russie. | | Le permien d'Oural, gouv. Oufa et Orenbourg. |
|---|---|---|---|---|
| Thuringien. | "Zechstein." | $P_3$ Tattarien | | Marnes bigarrés avec les conchifères. |
| | | $P_2$ | | Calcaires et marnes avec la faune de Zechstein, gypse. Les grès cuivreux avec les plantes fossiles (*Chelepteris*, *Sphallopteris*, *Bathypteris*, et *Anomorrhœa*). |
| Saxonien. | "Rothliegendes." | $P_1$ | | Marnes bigarrés, argiles, grès ou avec la faune marine: *Productus Cancrini*, *Strophalosia horrescens*, ou avec les plantes fossiles (*Calamites gigas*). |
| Artinskien ou Autunien. | "Permo-houillers." | P.C. | Koungourien. | Calcaires dolomitiques (*Productus Cancrini*, *Marginifera typica*, *Dielasma elongata*, *Fusulina Verneuili*). |
| | | | Artinskien. | Grès d'Artinsk, avec les plantes fossiles et ammonitidés. |

* Compiled from Lapparent and other sources.

## **Zalesskya gracilis,** Eichwald, sp. (Pl. I. figs. 1–3; Pl. II. figs. 4, 5, 8; Pl. III. figs. 9–20.)

1860. *Chelepteris gracilis*, Eichwald, *Lethæa Rossica*, vol. i., p. 98., pl. iii. figs. 4–5 (? *non* fig. 6).
1869. *Chelepteris gracilis*, Schimper, *Traité d. paléont. végét.*, vol. i., p. 702, pl. li. fig. 4 (? *non* fig. 5).

The description of this species is based upon a portion cut from the lower end of the type specimen figured by Eichwald in his *Lethæa Rossica*, Taf. iii., fig. 4. A photograph of the complete fossil by Mons. R. Koch was kindly forwarded to us by Mons. Zalessky, and is reproduced in Plate I., fig. 1.

As seen in transverse section, the greater part of the fossil is in an excellent state of preservation, although the central tissues have unfortunately disappeared. The most conspicuous part of the stem is the very wide stele (fig. 2, *st.*), which is 13 mm. in diameter. The stele is surrounded by a very wide thin-walled cortex, more of which is preserved on one side than on the other. At its widest the cortex is about 20 mm. thick, but even there it certainly does not represent the whole thickness of the stem. So far as it is present, the cortex is all thin-walled parenchyma except a narrow border at the very periphery of its widest part (fig. 2, *sc. C.*). At this region the cortical elements somewhat suddenly become thick-walled and brown-coloured. In all probability this represents the inner limit of an outer sclerotic cortical zone such as occurs in the other *Osmundaceæ*, both fossil and living. The inordinate width of the thin-walled inner cortex (fig. 2, *i.c.*) is a striking feature in our fossil.

The cortex is traversed on all sides by a very large number of departing leaf-traces, which arise from the stele in a close spiral. Here and there roots are also cut across in various directions as they pass outwards. Each leaf-trace is accompanied by a sheath of thin-walled inner cortex as it passes through the sclerotic zone (fig. 2, *A*). Unfortunately, our sections do not include the extreme periphery of the stem, and there is no indication of the leaf-bases becoming free from one another.

### The Structure of the Xylem.

The xylem of the stele forms a broad and perfectly continuous ring surrounding a central empty space (fig. 2). At one point in the stele a portion of it has been torn away, but elsewhere the ring measures 1·8 to 1·3 mm. in thickness. It was undoubtedly still wider in the living condition, for its inner margin is bordered at many places by the remains of crushed and flattened elements (figs. 3 and 4, *x.*). Some six or seven series of these crushed elements are present, and if they were imagined to have retained their original form and size, the xylem ring would be about ·9 mm. wider. Therefore the maximum width of xylem for which we have actual evidence is about 3·2 mm. But at the same time the complete ring is 12 mm. in diameter, and therefore there remains a space 5·6 mm. wide in the middle of the stele still unaccounted for.

There is no reason to believe that this actually represents an empty space in the living plant; on the other hand, it was doubtless occupied by some kind of tissue.

The xylem is composed of tracheides alone, without any trace of xylem parenchyma. The peripheral elements of the ring (figs. 3 and 4, *o. xy.*) are most distinctly smaller than the more central (figs. 3 and 4, *i. xy.*), and their average size increases gradually towards within until a certain point is reached not far from the inner margin of the ring. At this point a distinct change is noticeable in the general aspect of the xylem, owing to the presence of a number of conspicuously larger tracheides. In fact, two definite zones may be distinguished in the xylem ring, although the difference between the two kinds of xylem is not very pronounced in transverse section. In longitudinal section, however, the outer xylem zone is seen to consist of very elongated elements with slowly tapering and often very finely pointed ends (fig. 4, *o. xy.*), which appear to have undergone much sliding growth. On the other hand, the elements of the inner zone, and especially the larger ones, are comparatively short, and they are somewhat contorted in form (fig. 4, *i. xy.*). They are also more or less square-ended, with transverse or at most slightly oblique terminal walls. Wherever the flattened elements at the inner margin are sufficiently well preserved, they show the same characteristics as those of the inner xylem.

Close within the external periphery of the xylem ring occur some twenty to twenty-five well-defined mesarch groups of protoxylem, evenly distributed all round the stele (fig. 3, *prx.*, and fig. 11). These protoxylems are really the downward prolongations of the protoxylems of the leaf-traces, which are decurrent for some distance into the xylem of the stem, gradually dying out below. It is possible to regard the small elements that line the outer periphery of the stele as a continuous exarch protoxylem proper to the stem itself, and apart from the decurrent mesarch protoxylems of the leaf-trace. At the same time, however, they are rather large for protoxylem elements, and they do not differ in form or in the nature of their pitting from the contiguous elements of the metaxylem.

The mesarch protoxylems decurrent from the leaf-traces consist of a few very small tracheides, which are typically scalariform; that is to say, each of their walls has only one series of pits. On the other hand, the elements of the rest of the xylem have two or more vertical series of pits on almost every wall. It is only on the narrower walls, up to about 40 $\mu$ broad, that a single series is found (fig. 5 *a*). A more frequent marking is that of two regular vertical series of more or less horizontally elongated oblong pits (figs. 5 *b* and *c*). The unpitted region separating the two series varies considerably in breadth, and should it exceed a certain limit, a third series of pits appears in the middle of the wall (fig. 5 *d*). The pits of this middle series are usually smaller and more irregular than those of the lateral, being oval or almost rounded in outline. More rarely three or even four regular series of pits, all similar in size and form, are met with (figs. 5 *e* and *f*). When the number of series is still greater the pits are usually quite irregular in arrangement and oval or elliptic in outline (figs. 5 *g* and *h*). In the large elements of the inner zone of xylem this irregularity in arrangement is so great and the pits are so numerous that the thickened part of the

wall separating them appears as a delicate reticulation. In fact, in this last case they might very well be described as porose. The end walls of the tracheæ are marked with the same pattern as the side walls. In the transverse section of this fossil the tracheal walls are represented in such a manner that a considerable amount of structural detail is visible in the substance of the wall itself. In its best state of preservation the tracheal wall is represented by a brown-coloured substance showing up in the matrix of the fossil. The brown tract is delimited from the cavities of the tracheides that it separates by very fine black lines. These are usually most conspicuous at the angles and at the unpitted regions of the wall (figs. 8 *b*, *c*, and *d*), but they are often more or less broken up, and may even be absent altogether. A varying number of thin black lines also occur in the median region of the brown tract that represents the wall (figs. 8 *a*–*d*). These are of different lengths and are separated from one another by the homogeneous brown substance of the tract in which they lie. Similar black lines also occur at the angles where three or more tracheæ meet (figs. 8 *a*–*d*). They may either meet at the very centre of the angle to form a three- or four-rayed figure, or they may delimit one or more sides of an angular mass of the homogeneous brown substance occupying that position. In either case they radiate out shortly into the walls that meet at the angle, but they never become continuous with the other dark lines that lie in the substance of these walls.

From comparison with longitudinal sections it is clearly seen that the longer of these black lines in the median region of the wall correspond to the several vertical series of pits. Thus, if there is one series of pits, there is a single long black line (fig. 8 *a*); if two or more series of pits, there are two or more black lines of equivalent length (fig. 8 *b*). Here, however, a difficulty arises, for very often a very short line is also present between the longer lines which correspond to the pit series, and this cannot be referred to any pit at all (figs. 8 *c* and *d*). In many parts of the fossil the walls sometimes appear to have become more or less disorganised and dissolved before fossilisation. This breaking down usually occurs in the middle of the wall, and affects either an unpitted region or else the middle series of pits (fig. 8 *f*). Sometimes the wall is broken down at several places, or even along its whole length (fig. 8 *e*). In these regions the brown-coloured substance is partially or entirely absent, and the wall is represented by a thin black line alone.

The peculiarities just described in *Zalesskya gracilis* and also others noted in the species of *Osmundites* dealt with in Part I. of this paper were so difficult to correlate with the generally accepted idea of the structure of a fern tracheide that a careful re-examination of the xylem of the living *Osmundaceæ* was rendered necessary. This investigation was carried out by one of us, and the results, which are here shortly summarised, will be published in detail as a separate paper in a forthcoming number of the *Annals of Botany*. Contrary to expectation, it was found that the middle substance of the mature wall separating two contiguous tracheæ is entirely wanting in the regions of the pitted areas. In fact, the middle lamella and the primary walls

of the young tracheæ only persist at the angles where the tracheæ meet and in the areas separating the vertical series of pits (fig. 6). The opposing bars of secondary thickening that separate the several pits of each vertical series are quite free from one another in the median vertical plane in the long axis of the wall. If there is only one series of pits, the opposing bars of the two contiguous tracheæ run freely across from one corner to the other without coming into contact with one another. If there are several vertical series of pits, the bars are cemented together by an intervening middle substance at the intervals between each series of pits.

In the transverse section of such a wall an empty space will be seen in the middle of its substance corresponding with the position of each vertical series of pits, whereas the angles and the intervals between the series of pits will be solid throughout (fig. 6). In applying these facts to the fossil *Osmundaceæ*, no difficulty is met with in the cases of *Osmundites Dunlopi*, *O. Gibbiana*, and *O. skidegatensis*. In these the walls are represented by their dark carbonaceous remains, and wherever detail is preserved their appearance fits in accurately with the description of the recent *Osmundaceæ* given above. This is best shown in *Osmundites skidegatensis* (fig. 7), where the transverse section of the tracheal wall shows two black bars separated by white spaces in the pitted regions, but connected up by a black mass in the unpitted regions and at the angles where the tracheæ meet.

We feel satisfied that in the living *Zalesskya gracilis* the tracheal wall also possessed the same structure, although it is somewhat masked in the fossil owing to some peculiarity in its method of fossilisation. Indeed, in some of the sections a structure similar to that of *Osmundites skidegatensis* is clearly present in the root-steles and leaf-traces (fig. 20). Elsewhere it appears that the disintegrated carbonaceous substance of the wall, during the processes of partial decay and fossilisation, has become redeposited on the surfaces of the wall, both on the internal surfaces of the lumens of the tracheæ and on the limiting surfaces of the empty spaces in the substance of the walls, producing the thin black lines referred to above. This still leaves the black lines at the angles and the short lines opposite unpitted areas in the wall unexplained. It does not seem probable that these represent cavities existing in the living material, but they may indicate the position of tracts of some less resistant substance than lignin in the tracheal wall, which, by its early decay after the death of the plant, formed cavities in the wall before actual fossilisation took place.

### Structure of Phloem and Cortex.

The xylem is surrounded by a continuous ring of phloem (figs. 3 and 9, *ph.*), separated from the tracheæ by a broad zone of some five to six layers of vertically elongated parenchymatous cells forming the xylem sheath (figs. 4 and 9, *xy. sh.*). Some of these cells are filled with a dark brown substance which sometimes appears granular, and the innermost often have their angles marked by dark lines similar to those that occur at the angles of the tracheae. Probably the walls at these points were more or less

lignified, as is actually the case in the corresponding cells of *Osmunda cinnamomea*. The phloem ring is a broad one, and consists for the most part of large and conspicuous sieve-tubes (figs. 9 and 10), amongst which a few elements are interspersed which may be regarded as phloem parenchyma (fig. 10, *ph. par.*). These are much smaller than the sieve-tubes in size, and have somewhat firmer walls. The sieve-tubes were very elongated and tubular (fig. 4, *ph.*), with stout but somewhat soft walls, for in most places they are much distorted and often pressed flat, so that the lumen is almost obliterated. Where they are well preserved, a thin brown outline is visible inside the sieve-tube, suggesting a pellicle of some substance that has separated off from the wall and become more or less contracted and folded (fig. 10, *pel.*). It may have been the inner layer of the wall, or possibly represents the contents. No suggestion of a "porose layer" or a protophloem could be detected in any part of our sections, transverse or longitudinal. On the contrary, towards the outside, the phloem is directly continuous with a zone of four or five layers of parenchymatous cells, conspicuous in the fossil owing to the dense dark brown colour of their contents (figs. 4 and 9, *per.*). These contents are not homogeneous, but exhibit a curious vesicular structure varying in texture from a coarse foam to one so fine that it might almost be described as granular. The cells of this layer are angular in outline, and fit into one another without leaving intercellular spaces. Those of the innermost layers are comparatively small and vertically elongated; towards without they increase in size, becoming at the same time shorter, and thus they pass over gradually into the parenchyma of the inner cortex. This innermost zone must be regarded as a pericycle, although it is admittedly not marked off from the cortex by any definite single layer comparable to an endodermis. At the same time, the stele as a whole has a fairly sharp external contour, for the cells of the inner cortex distinguish themselves from those of the pericycle by the general absence of the dense brown contents and by the presence of well-marked intercellular spaces at the corners (fig. 3). The broad inner cortex consists of thin-walled parenchymatous ovoid or rounded cells, with intercellular spaces at the angles. In most of the cells the contents have been completely disintegrated, but a considerable number are filled with a brown vesicular substance similar to that described in the cells of the pericycle. Judging from the contents of the cells in a corresponding position in the recent *Osmundaceæ*, and also in some of the fossil forms (*Osmundites skidegatensis*, *O. Dowkeri*), the vesicular masses probably represent aggregates of starch grains in various grades of decomposition. This is the more probable because in those parts of the cortex where the cells are best preserved the vesicular mass resolves itself into a number of separate contiguous spherical outlines.

At the periphery of the widest part of the cortex the cells gradually become narrower and somewhat more vertically elongated. At the same time their walls become much thicker and dark brown in colour (fig. 2, *Sc. C.*). This region doubtless represents the inner margin of a sclerotic outer cortex, the greater part of which is wanting in our specimen.

### The Leaf-trace.

The leaf-trace departs from the stele of the stem in a perfectly protostelic manner. The protoxylem groups previously described (fig. 11) at the periphery of the xylem ring are all decurrent from the leaf-traces. The first sign of preparation for the departure of the leaf-trace is the appearance of a slight prominence on the periphery of the xylem ring opposite one of the mesarch protoxylems (figs. 12 and 13, *prx.*). Followed upwards, this develops into a broad, bluntly rectangular projection into which the protoxylem group passes (fig. 13). This projection gradually increases in size and eventually separates off as the xylem strand of a leaf-trace (fig. 14). While still enclosed within the phloem of the stem, the protoxylem of the leaf-trace is seen to be deeply mesarch, with a large amount of centripetal xylem on its adaxial side (fig. 14). Even after the leaf-trace as a whole has become completely free from the stele and has advanced some distance into the cortex, a considerable number of centripetal elements are still present (fig. 15, *a* and *b*).

In the close neighbourhood of the stele the transverse section of the xylem of the leaf-trace is oblong in outline, while the leaf-trace itself is oval (fig. 16). As it passes outwards both the xylem strand and the whole leaf-trace become curved round adaxially. This curvature gradually increases until in the outermost trace in our specimens the xylem strand has attained the form of a semicircle, while the leaf-trace itself is reniform (fig. 17). As the leaf-trace passes out the centripetal xylem gradually disappears, and by the time that the curve of the xylem strand has become at all pronounced it has entirely gone and the protoxylem is perfectly endarch (fig. 16, *prx.*). In a leaf-trace still further out the protoxylem group is seen to have divided, and in the outermost leaf-traces two or three protoxylem strands are present. No doubt the leaf-trace became still more curved and the protoxylems still more numerous in the outer region of the sclerotic cortex that is, however, wanting in our specimen.

The xylem of the leaf-trace is surrounded on all sides by a parenchymatous sheath two to four layers thick, and similar in appearance to the xylem sheath of the stem (fig. 16, *xy. sh.*). This tissue is followed by a continuous and well-developed zone of phloem consisting of large sieve-tubes and a few cells of phloem parenchyma. On the other hand, the closest examination failed to reveal any protophloem whatever, even on the abaxial side of the trace. While still in close proximity to the stele of the stem the leaf-trace is limited by a zone of some three or four layers of cells exactly similar in appearance to those that have been referred to as the pericycle in the stem. As the leaf-trace passes outwards, the contents of the inmost cells of this zone become less and less conspicuous, while those of the outermost layer become more dense and prominent. In fact, this layer gradually assumes the appearance of an endodermis (fig. 16, *en.*).

### The Root.

The roots arise singly or in pairs upon the stem stele at points immediately below the departure of certain of the leaf-traces. Many traces, however, are not provided

with roots. The xylem strands of the roots are inserted upon the sides of those of the leaf-traces just as the latter separate from the xylem of the stem (fig. 18, *r. st.*). The roots run more or less horizontally through the cortex, taking a sinuous course and turning aside from time to time to avoid a leaf-trace or another root.

When about half-way through the inner cortex of the stem they obtain a cortex of their own, which consists for the most part of very thick-walled fibrous sclerenchyma (fig. 19, *sc. r.*). The cells are smallest and thickest at the outside; towards within they increase in size, while their walls diminish in thickness. The last one or two layers next the endodermis are comparatively thin-walled. The cells of the endodermis are tangentially elongated and filled with brown, densely granular contents (fig. 20, *en.*). It probably consists of a single layer of cells, but it is difficult to make sure of this, for the adjacent cells sometimes contain an exactly similar substance.

The xylem strand is diarch and oval, with a few very small protoxylem elements at the two ends. The xylem is surrounded by a parenchymatous sheath two or three cells thick, and this is followed by the phloem, which is in considerable quantity on the sides of the xylem. It is possible also to distinguish protophloem on the outside of the two phloem groups (fig. 20, *pr. ph.*). The phloem is separated from the endodermis by two or three layers of pericycle similar to that of the stem in general appearance.

*Locality.*—Mine Kluczersky, district of Bjelebei, government of Orenburg, Russia.

*Horizon.*—Upper Permian (P2 of Geological Table, p. 219). Specimen preserved in the Museum of the Institute of Mines, St Petersburg.

## **Zalesskya diploxylon,** Kidston and Gwynne-Vaughan, n.sp.

(Pl. IV. figs. 21–28.)

The general appearance of this fossil suggests that it has undergone a considerable amount of change after mineralisation, owing to the percolation of water through the stone. The sections were of a light fawn colour, much of the carbonaceous matter originally present having been removed. However, a certain amount of this has been redeposited in the form of minute granules, flakes, and specks, and in some parts of the fossil as large irregular aggregations. The substance of the fossil as it exists at present is very porose and friable.

The transverse section of the specimen is circular, with a diameter of about 3·5 cm. (fig. 22). There is a fairly large stele measuring 7 mm. across. The greater part of the xylem is still preserved, but unfortunately the more central elements of the stele have crumbled away, owing to the friable nature of the fossil. The xylem is surrounded by a rather conspicuous ring of phloem, visible to the naked eye, and this in turn by a very wide cortex entirely composed of thin-walled parenchyma. In our specimen the whole of the outer part of the stem, and also the mantle of persistent leaf-bases that probably coated the stem proper in the living plant, have not been preserved. It follows, therefore, that the surface of the fossil as shown in fig. 21 represents a

"*Knorria*" or partially decorticated condition of the actual stem. The true external surface of the stem, and still more so that of the coating of leaf-bases, would present a very different appearance. Numerous leaf-traces and root-steles are cut through on their way out through the cortex. The former arise in a close spiral upon the stele.

### Structure of the Stele and Cortex.

As in *Zalesskya gracilis*, the xylem forms a perfectly continuous ring and the leaf-traces depart in a protostelic manner. The break in the xylem seen to one side of the stele (fig. 22) is obviously due to the crumbling away of the stone. This also accounts for the absence of tissue in the centre of the stele. Fig. 23 shows clearly that the broken inner margin is not the natural limit of the xylem, but the same tissue extended further in towards the centre of the stele. The whole mass of the xylem is 6·4 mm. in diameter, but the widest part of it still preserved only measures 2·5 mm. across. If, however, an equal amount of it had been preserved all round, the central area still unaccounted for would only be 1·4 mm. wide.

As in *Zalesskya gracilis*, xylem parenchyma is entirely absent, and two distinctly different regions can be observed in the xylem—a central and a peripheral (figs. 23 and 24). The contrast between the two kinds of xylem appears to be much more marked in *Zalesskya diploxylon* than in *Z. gracilis*, but this is perhaps due to the fact that we have so much more of the central xylem present in *Z. diploxylon* than in the other species. The elements of the outer xylem zone are very elongated, with more or less pointed ends. Those at its extreme periphery are not much smaller than the rest, but just where the outer zone borders on the central xylem there is a somewhat sudden and fairly distinct decrease in the general size of the elements (fig. 23, at $x$). The elements of the central xylem are much wider than those of the outer zone, and in longitudinal section the contrast between the two kinds of xylem is even more strongly marked than in the transverse (fig. 24). This is chiefly due to the fact that, in addition to being wider, the elements of the central xylem are also much shorter than those of the outer zone, and further, their terminal walls are transverse, or at most only slightly oblique (figs. 24 and 25). In fact, the tracheæ of the central xylem might well be described as inflated, oblong, or sack-shaped; some of the inner ones not being more than twice as long as broad.

The elements of both kinds of xylem have multiseriate pits, those of the outer zone having usually two vertical series of oblong pits; but in the central xylem as many as five regular series were observed. Where the pits are more numerous than this they are more or less irregularly arranged and the tracheæ have a reticulate or porose appearance. In spite of their parenchymatous and irregular form there is no doubt that even the inmost of the elements preserved belonged to the xylem, being in fact true pitted tracheæ. Further, we are strongly of the opinion that in the living plant similar elements filled up the whole of the vacant space that now occurs in the centre of the stele. In fact, we believe that the xylem was solid throughout.

As usual, the xylem is surrounded by a broad sheath of parenchyma some four to five layers thick (figs. 23 and 26, *xy. sh.*). Then follows a stout belt of phloem, consisting of from four to six layers of sieve-tubes without any intervening phloem parenchyma (fig. 26, *ph.*). The sieve-tubes are large and very elongated, and probably had fairly thick and firm walls, for in most parts of the section they have kept their form without much distortion. As in *Zalesskya gracilis*, nowhere in any of our sections is there any indication either of a protophloem or of any "porose layers." On the contrary, the large sieve-tubes abut directly upon a zone of parenchymatous cells occupying the position of a pericycle (fig. 26, *per.*). The latter is marked off from the cortex by an almost continuous ring of irregularly shaped aggregations of carbonaceous matter (fig. 26, *car.*), but no endodermis is recognisable.

The cortex consists throughout of oval or rounded parenchymatous cells with intercellular spaces at the corners. No remains of an outer sclerotic cortex have been left at any part of its periphery.

## The Leaf-trace.

The first sign of the departure of a leaf-trace from the stele is the appearance of a slight prominence on the surface of the xylem. This projection increases more and more towards above (fig. 27), until at last it is constricted off as the oblong xylem strand of the trace. In a leaf-trace some little distance from the stele the xylem strand is slightly reniform in outline, with a single median endarch adaxial protoxylem (fig. 28, *prx.*). The leaf-trace protoxylem is decurrent for some distance into the xylem of the stem as a mesarch strand, but it dies out much more rapidly than in *Zalesskya gracilis*. In fact, it has already disappeared by the time that the prominence of the leaf-trace xylem is no longer recognisable. In our sections the leaf-traces in closest proximity to the stele have all fallen out, so it could not be determined whether any centripetal xylem accompanied the leaf-trace from the stem stele or not.

As the leaf-trace passes outwards the curvature of its xylem strand gradually increases until in the outermost traces it has assumed the form of a low arch. At the same time the median protoxylem divides first of all into two and ultimately into several separate strands. The outline of the whole leaf-trace passes through a similar series of changes, although it always remains considerably less curved than its own xylem strand.

In several of the leaf-traces the tissues are fairly well preserved, and it can be made out that there are two or three layers of parenchyma separating the xylem from the phloem (fig. 28). The phloem, which completely surrounds the leaf-trace, is in greatest abundance in the median region on both sides of the trace, and particularly on the adaxial side, where it may consist of as many as six or seven layers of sieve-tubes. As in the stem, it appears to consist of sieve-tubes only without any phloem parenchyma. The preservation was not sufficiently good to determine the presence or absence of a protophloem. Around the phloem are three or four layers of cells, which may be

regarded as a pericycle, and the limit of the whole leaf-trace is marked by a ring of black carbonaceous matter (fig. 28, *car.*).

### The Root.

The roots arise singly or in pairs directly on the stele. Their xylem strands are attached directly to the xylem of the stele in a line with, but below, the point of departure of a leaf-trace xylem. On their way through the cortex they first of all run towards the apex of the stem (fig. 22, *r.*), and then they turn outwards and their course becomes very irregular. Their xylem strands are diarch, and they do not attain a cortex of their own, so far as could be observed in our specimen.

*Locality.*—Found in the same collection as *Zalesskya gracilis*, Eichwald, sp., but without label. The specimen is, however, believed to have come from the same locality.

Specimen preserved in the Museum of the Institute of Mines, St Petersburg.

## Zalesskya, n.g.

Fern stems of considerable size. Leaves spirally arranged. Axis occupied by a single central protostele. Xylem forming a stout continuous ring, or solid to the centre. Xylem differentiated into two regions—a peripheral zone of normal tracheæ and a more central region of short, wide vesicular elements. Tracheæ with multiseriate pits. Phloem well developed, separated from the xylem by a stout xylem sheath. Protophloem and porose layers absent. Stele surrounded by a *very wide* parenchymatous cortex; outer cortex probably sclerotic. Leaf-trace and its xylem strand at first ovoid in transverse section, with a median mesarch protoxylem near the adaxial side; further out horse-shoe shaped, with the concavity adaxial and with several endarch protoxylems.

### General Considerations.

The most interesting points brought to light by the investigation of the genus *Zalesskya* are, first of all, the absolute confirmation of the occurrence of a completely continuous and perfectly protostelic xylem ring in the vascular anatomy of the *Osmundaceæ*, and, secondly, the marked distinction that exists between the elements of the peripheral and those of the more central regions of the xylem. The peripheral xylem zone is obviously represented in the recent *Osmundaceæ* by the ring of xylem strands that occurs in the stele, but the central xylem, with its short, wide reticulate or porose elements, appears to have been lost in the existing forms.

As regards *Zalesskya diploxylon*, at any rate, we feel convinced that the central xylem occupied the whole of the centre of the stele in the living plant. Further, we accept the deduction suggested by this conclusion, *that the vascular anatomy of the Osmundaceæ must be derived from a protostele with a solid central homogeneous*

*xylem mass.* In fact, these fossils seem to disclose some of the steps by which the transition actually took place. In *Zalesskya diploxylon* the central tracheæ have become short and wide, and seem to have changed their water-carrying function for one of water-storing. In the recent and the more advanced forms they have become still further modified, and, losing all trace of their original tracheal nature, they have given rise to a thin-walled parenchymatous pith. From this point of view it is clear that *the central ground-tissue of the recent Osmundaceæ must be regarded as phylogenetically derived by modification from the central xylem of a solid protostele, and that primitively it had no relation or connection with the cortex whatever.* The vascular anatomy of the *Lepidodendreæ* and *Sigillariæ* provides an instructive and closely parallel series of developments. A similar advance is made, starting from a homogeneous solid mass of xylem (*L. rhodumnense*, etc.), through such a form as *L. vasculare*, which has a pith intermingled with short isodiametric tracheæ, leading on to forms with a pure pith (*L. Harcourtii*, etc.). The next stage is the partial breaking up of the narrow xylem ring as seen in *Sigillaria spinulosa* (Scott, *Studies in Fossil Botany*, p. 200), until finally a stage is reached in which the xylem strands are completely separate from one another, as in *Sigillaria Menardi* (Brongniart, *Observations sur la Structure du Sigillaria elegans*, pl. xxv., figs. 3 and 4; pl. xxvii., fig. 1). At this point reference should be made to an interesting observation by Seward and Ford in their paper on the anatomy of *Todea* (*Trans. Linn. Soc. Lond.*, vol. vi., pt. 5, 1903, pp. 248 and 249). They record the occasional occurrence of short, wide tracheæ with reticulate thickenings at the inner margins of the xylem strands of *Todea superba* and *T. hymenophylloides.* The former is figured on pl. xxix., figs. 30 and 31. These elements may perhaps be regarded as the vestigial remains of the ancestral central xylem.

The peripheral tissues of the stele in the living *Osmundaceæ* possess some special characters of exceptional interest and peculiar to the order—in particular, the absence of a true protophloem and the presence of the so-called "porose layers" on the outside of the metaphloem. In *Zalesskya* both these tissues are absent, and the large sieve-tubes of the metaphloem abut directly upon a zone of parenchyma that we have called the pericycle. It appears, therefore, that the porose layers are a relatively late development, and that Seward and Ford are right (*l.c.*, p. 242) in regarding it as derived from the pericycle. In the Osmundaceous affinity the phloem of the stem has never become differentiated into protophloem and metaphloem, not even in the most advanced forms. On the other hand, a well-developed protophloem is present in the leaf-trace of the recent genera and also in *Osmundites skidegatensis.*

As regards the zone of tissue that we have called the pericycle in these two fossils, it only deserves the name in virtue of its position. No real delimitation is possible between its cells and those of the inner cortex, and there is no definite layer that can be identified as an endodermis. In fact, the state of affairs in these primitive forms would be best expressed by saying that the phloem of the stele was surrounded by a narrow

sheath formed by slightly specialised cells of the inner cortex. An endodermis might have been demonstrable in the living plant as in the modern genera, and whenever it is present it must have been differentiated from the outer cells of this sheath, which may account for the slight irregularities which it frequently shows in the recent forms. These observations on the phloem and pericycle are, of course, far too limited to do more than provide mere suggestions as to the origin of these tissues. A complete knowledge of this region of the stele in other primitive members of the order is necessary before any confident conclusions can be reached.

Owing to the decorticated nature of our specimens, it is unfortunately impossible to say whether the base of the petiole possessed stipular wings or not, and no comparisons can be made with the structure of the petiole in the other members of the *Osmundaceæ*. It should be mentioned, however, that in *Zalesskya* there is no alternation of scale-leaves and foliage-leaves such as occurs in the recent genera and in the Jurassic representatives *Osmundites Dunlopi* and *O. Gibbiana*. The mesarch position of the protoxylem in the leaf-trace when still in close proximity to the stem stele is, we believe, a point of considerable importance; but since another Osmundaceous fossil to be described in the next part of this paper promises to throw some light upon the point, it will be best to leave it over for future consideration.*

## DESCRIPTION OF FIGURES.

Figs. 8 *a–f* are from drawings; all the others are from untouched photographs.

The following lettering is used throughout: *xy.*, xylem; *prx.*, protoxylem; *ph.*, phloem; *S.T.*, sieve-tubes; *per.*, pericycle; *C.*, cortex; *l.t.*, leaf-trace; *r.*, root.

### Plate I.

Fig. 1. *Zalesskya gracilis.* External surface of the whole fossil. Nat. size. (Photograph by Mons. R. Koch; forwarded by Mons. M. Zalessky.)

Fig. 2. *Zalesskya gracilis.* A complete transverse section. *st.*, stele; *Sc. C.*, sclerotic cortex; *i. C.*, parenchymatous cortex; *A.*, tract of inner cortex accompanying the leaf-trace through the sclerotic outer cortex. × about 2½. (Slide 1253.)

Fig. 3. *Zalesskya gracilis.* Portion of the vascular ring in transverse section. *o. xy.*, outer xylem; *i. xy.*, inner xylem. The black band at *x* represents crushed tracheides. × 30. (Slide 1253.)

### Plate II.

Fig. 4. *Zalesskya gracilis.* The vascular ring in longitudinal section. *xy. sh.*, xylem sheath. × 30. (Slide 1258.)

Fig. 5. *Zalesskya gracilis.* Surface views of the tracheal walls as seen in longitudinal section. *a*, a single vertical series of pits; *b*, two such series; *c*, two series widely separated; *d*, three series, the median one being smaller than the lateral; *e*, three series all similar; *f*, four equal series; *g*, reticulate or porose pitting; *h*, terminal wall between two reticulate or porose elements. × 250. (Slides Nos. 1255, 1256, 1257, 1258.)

* We beg to acknowledge our indebtedness to the Executive Committee of the Carnegie Trust for a grant to defray the cost of the plates illustrating Parts I. and II. of this paper.

Fig. 6. *Osmunda cinnamomea.* Wall between two xylem elements. × 600.

Fig. 7. *Osmundites skidegatensis.* Transverse section of the xylem showing the structure of the walls of the tracheæ. × 180. (Slide 1251.)

Fig. 8. *Zalesskya gracilis.* Transverse sections of the walls of the xylem elements. *a*, a single series of pits, each represented by a black line in the substance of the wall; *b*, two series of pits; *c*, ditto with an additional small black line; *d*, three series of pits with additional small black lines; *e* and *f*, imperfectly preserved walls. × about 600.

## Plate III.

Fig. 9. *Zalesskya gracilis.* Transverse section of the peripheral tissues of the stele. *xy. sh.*, zone of parenchyma separating xylem from phloem; *in. c.*, inner cortex. × 50. (Slide 1252.)

Fig. 10. *Zalesskya gracilis.* Transverse section of the phloem; *S. T.*, sieve-tubes; *pel.*, pellicle within the sieve-tubes; *ph. par.*, phloem parenchyma; *xy. sh.*, xylem sheath. × 260. (Slide 1252.)

Fig. 11. *Zalesskya gracilis.* Transverse section of the periphery of the xylem showing a mesarch protoxylem group. × 80. (Slide 1253.)

Fig. 12. *Zalesskya gracilis.* Transverse section of the periphery of the xylem showing the first indication of the departure of a leaf-trace. × 30. (Slide 1253.)

Fig. 13. *Zalesskya gracilis.* The departing leaf-trace at a point higher up than that shown in fig. 12. × 30. (Slide 1235.)

Fig. 14. *Zalesskya gracilis.* The leaf-trace with its xylem just free from the xylem of the stele. × 30. (Slide 1252.)

Fig. 15 *a* and *b*. *Zalesskya gracilis.* Transverse sections of two different leaf-traces in close proximity to the stele. The protoxylem is still mesarch. × 40. (Slide 1253.)

Fig. 16. *Zalesskya gracilis.* Transverse section of a leaf-trace some distance out in the cortex. *xy. sh.*, xylem sheath; *ad. ph.*, adaxial phloem; *ab. ph.*, abaxial phloem; *en.*, endodermis. × 90. (Slide 1253.)

Fig. 17. *Zalesskya gracilis.* Transverse section of one of the outermost leaf-traces in the specimen. × about 12. (Slide 1253.)

Fig. 18. *Zalesskya gracilis.* Transverse section of the periphery of the stele showing the departure of the root steles; *r. st.*, root steles. × 20. (Slide 1252.)

Fig. 19. *Zalesskya gracilis.* Transverse section of a root when still in the cortex of the stem; *sc. r.*, sclerotic cortex of root. × 22. (Slide 1260.)

Fig. 20. *Zalesskya gracilis.* Transverse section of the stele of the same root more highly magnified. *pr. ph.*, protophloem; *en.*, endodermis. × 110. (Slide 1260.)

## Plate IV.

Fig. 21. *Zalesskya diploxylon.* External surface of the specimen. Nat. size. (Photograph by Mons. R. Koch; forwarded by Mons. M. Zalessky.)

Fig. 22. *Zalesskya diploxylon.* A complete transverse section of the specimen. *st.*, stele. × about 2½. (Slide 1268.)

Fig. 23. *Zalesskya diploxylon.* Transverse section of a portion of the stele. *o. xy.*, outer xylem; *cen. xy.*, central xylem; *x.*, inner limit of outer xylem zone. × 30. (Slide 1268.)

Fig. 24. *Zalesskya diploxylon.* Longitudinal section of the stele. Lettering as in fig. 23. × about 14. (Slide 1271.)

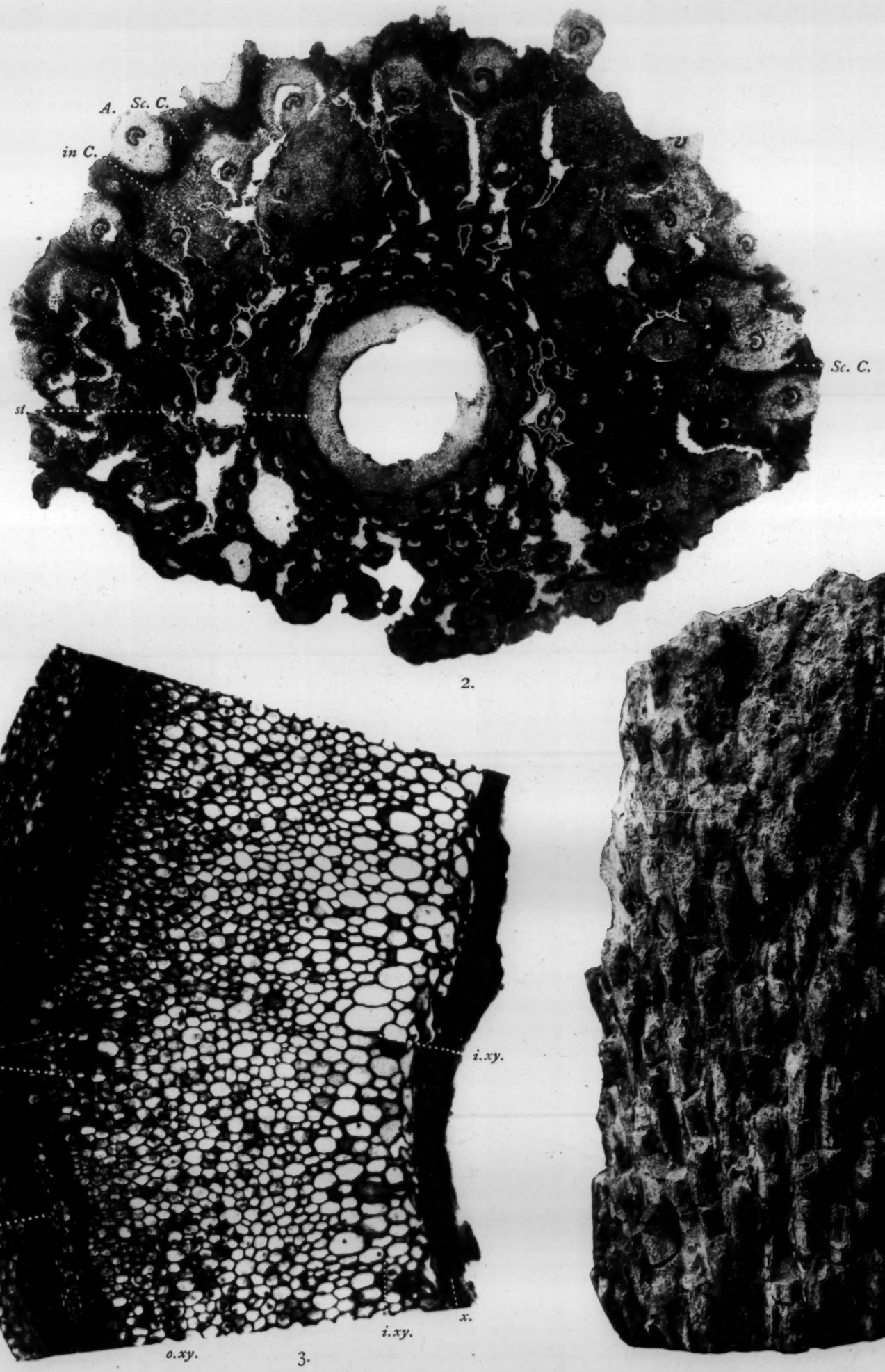
Fig. 25. *Zalesskya diploxylon.* Longitudinal section of a portion of the central xylem. × 35. (Slide 1271.)

Fig. 26. *Zalesskya diploxylon.* Transverse section of the peripheral tissues of the stele. *car.*, zone of carbonaceous matter. × 65. (Slide 1268.)

Fig. 27. *Zalesskya diploxylon.* Transverse section of the periphery of the stele showing a departing leaf-trace. × 30. (Slide 1268.)

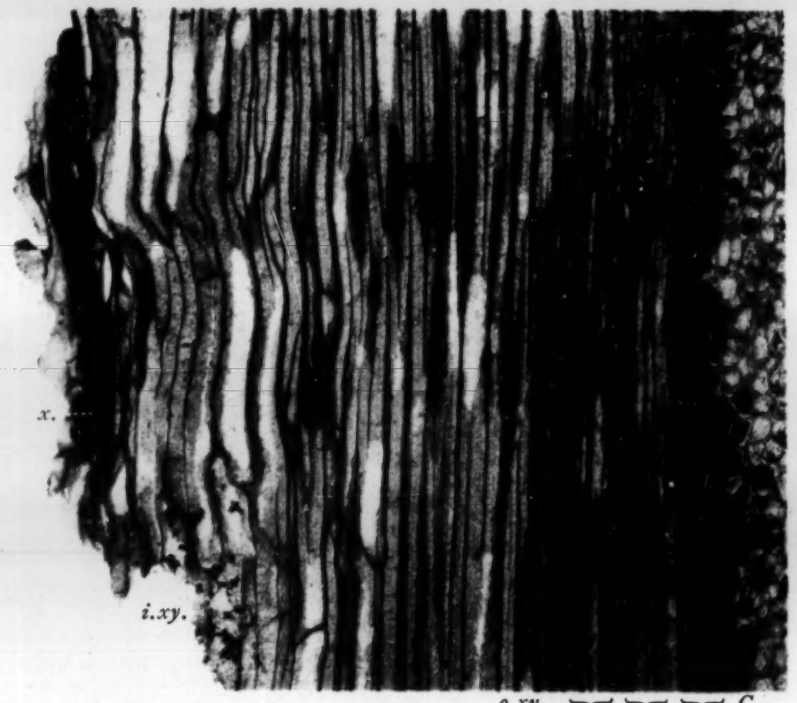
Fig. 28. *Zalesskya diploxylon.* Transverse section of a leaf-trace in the cortex of the stem. *ad. ph.*, adaxial phloem; *ab. ph.*, abaxial phloem; *car.*, ring of carbonaceous matter. × 30. (Slide 1269.)

KIDSTON AND GWYNNE-VAUGHAN: FOSSIL OSMUNDACEÆ. PART II. PLATE I.




ZALESSKYA GRACILIS. Eichwald sp.

KIDSTON AND GWYNNE-VAUGHAN: FOSSIL OSMUNDACEÆ. PART II. PLATE II.

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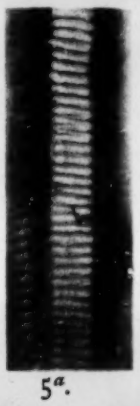

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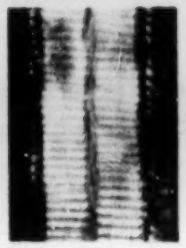

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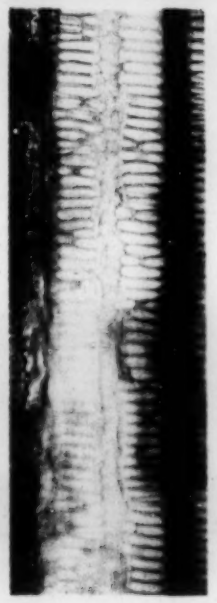

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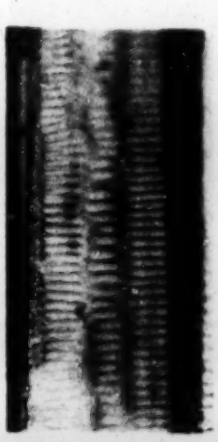

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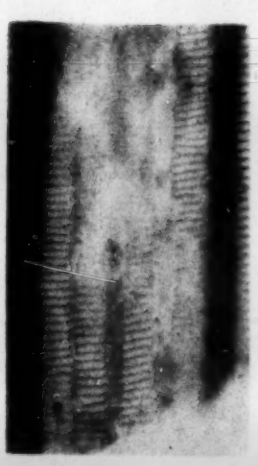

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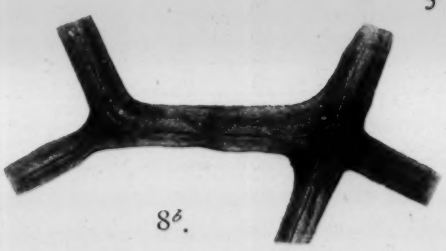

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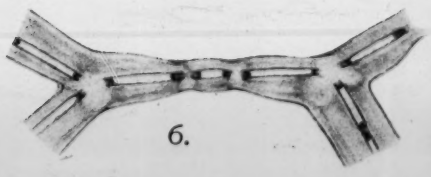

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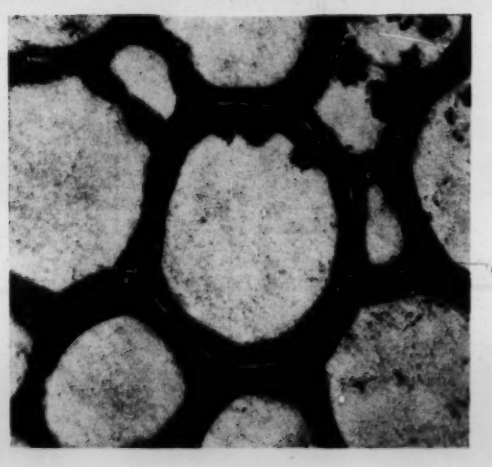

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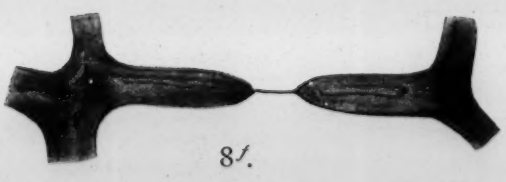


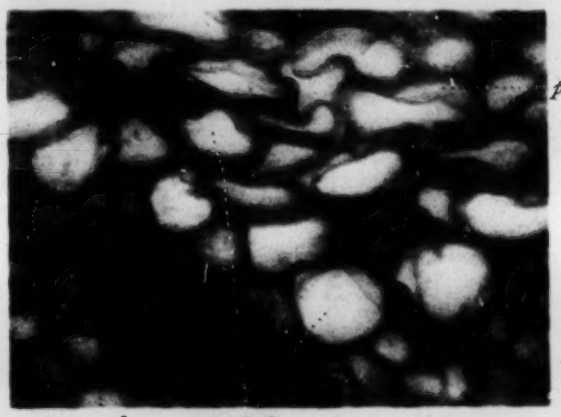
8f.

8a.

Figs. 4, 5. ZALESSKYA GRACILIS. Eichwald sp.
Fig. 6. OSMUNDA CINNAMOMEA. Linn.
Fig. 7. OSMUNDITES SKIDEGATENSIS. Penhallow.
Fig. 8. ZALESSKYA GRACILIS. Eichwald sp.

KIDSTON AND GWYNNE-VAUGHAN: FOSSIL OSMUNDACEÆ. PART II. PLATE III.

9.



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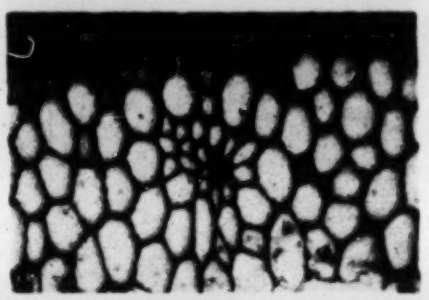
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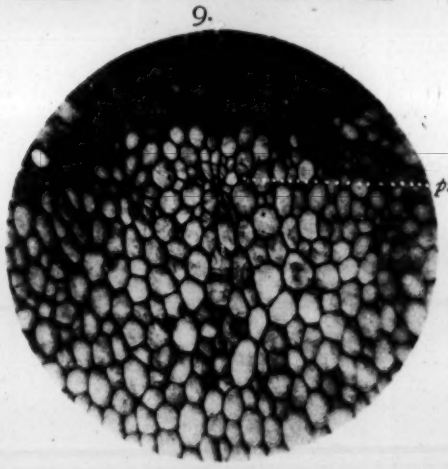

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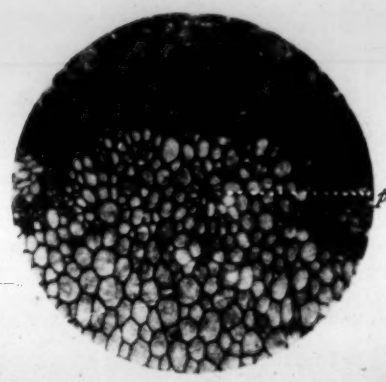

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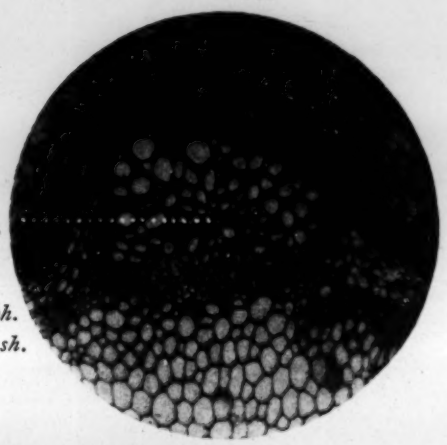

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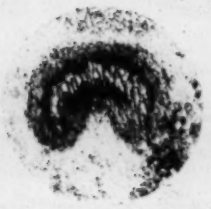
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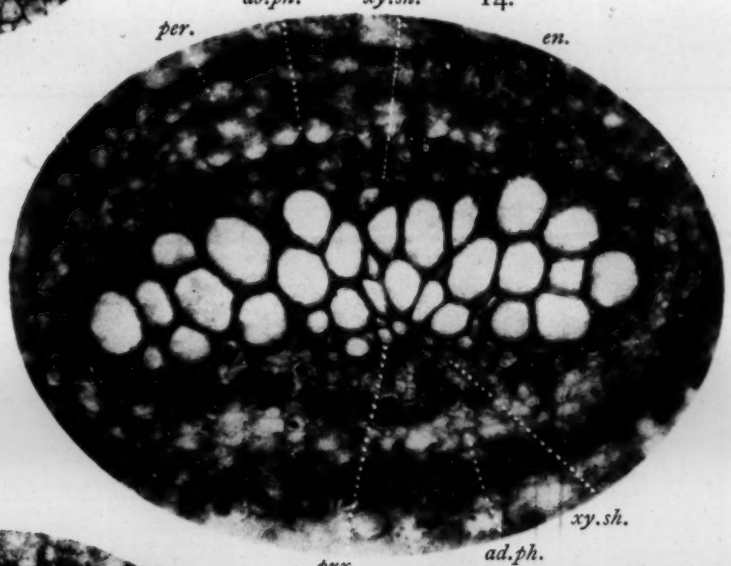

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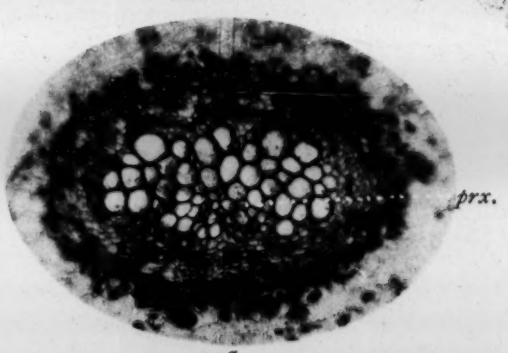

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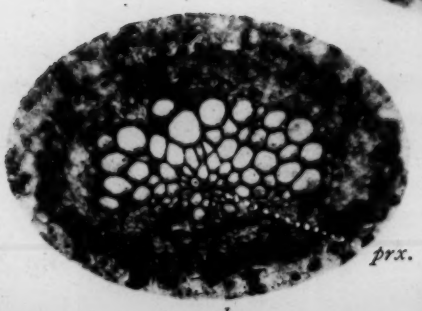

15[b].

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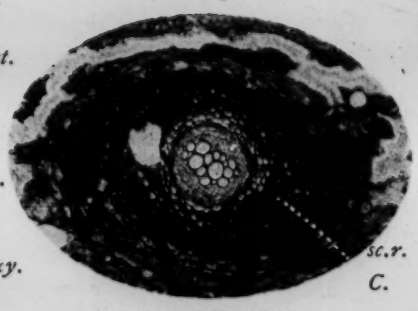
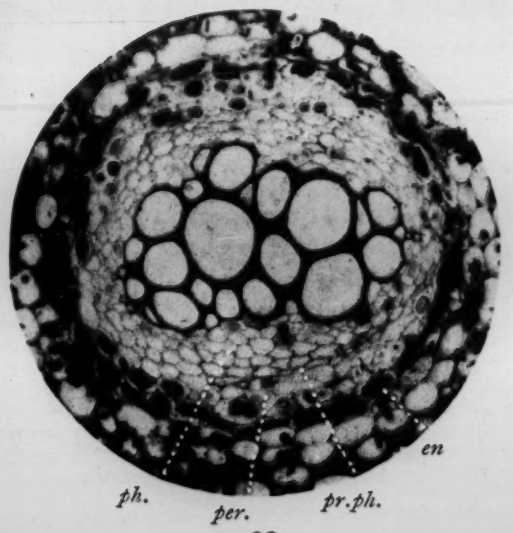


19. *C.*



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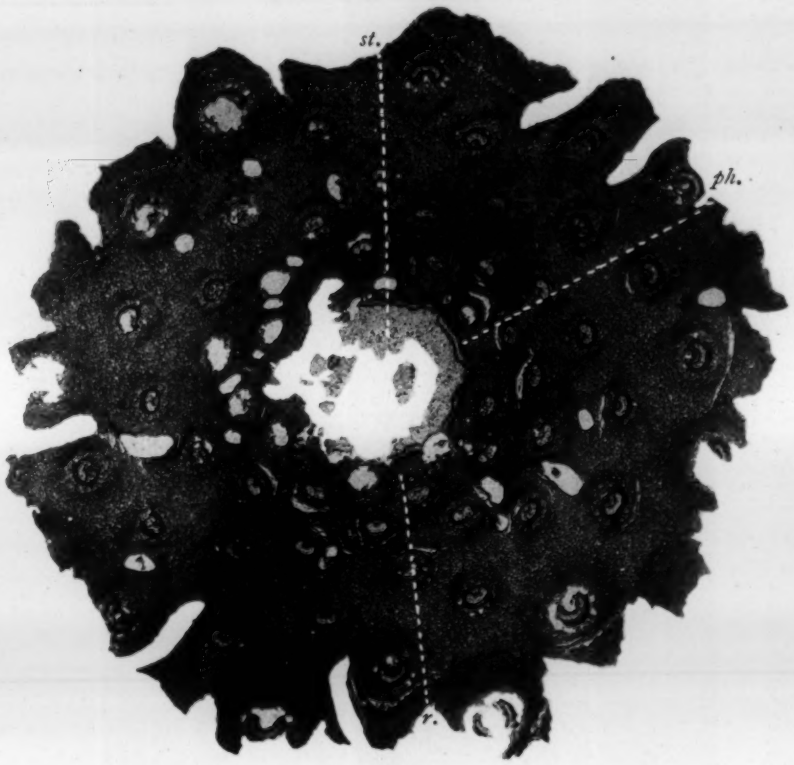
ZALESSKYA GRACILIS. Eichwald sp.

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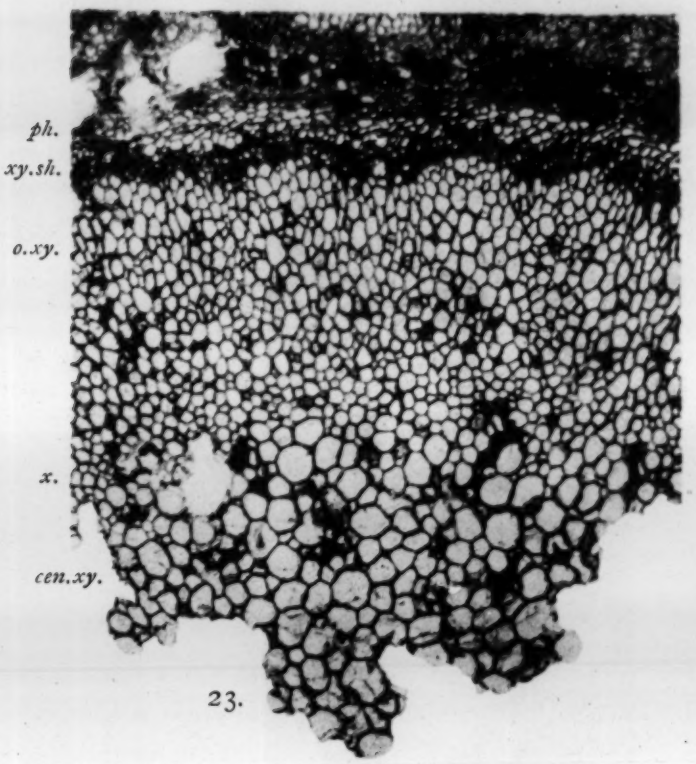


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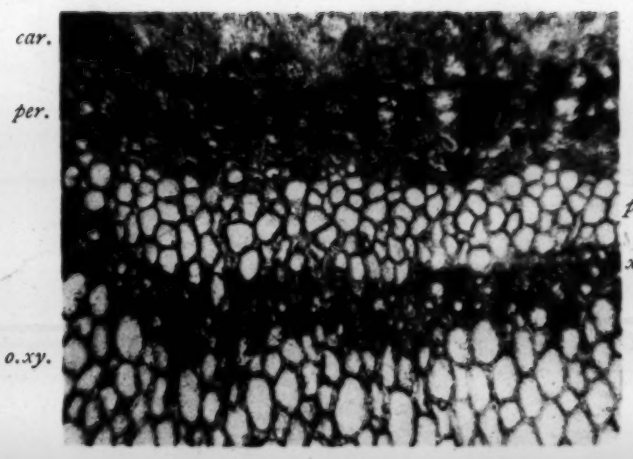


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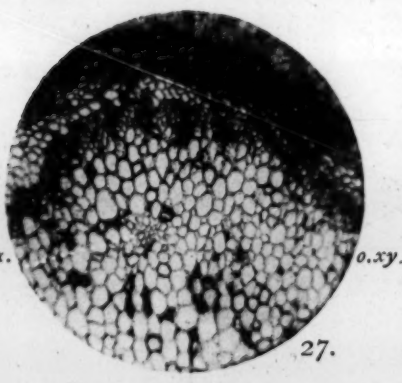


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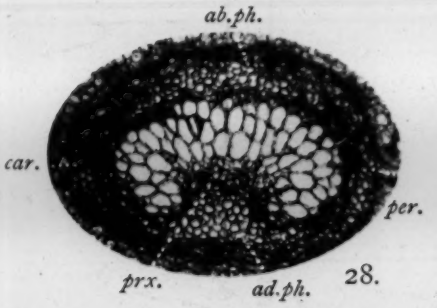


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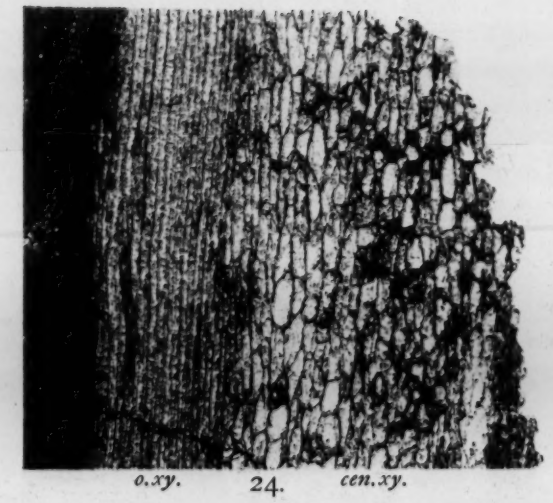


24.

25.

ZALESSKYA DIPLOXYLON. Kidst. and G-V.

# X.—The Medusæ of the Scottish National Antarctic Expedition.

By **Edward T. Browne**, Zoological Research Laboratory, University College, London. *Communicated by* Dr W. S. Bruce. (With Two Plates.)

(MS. received November 27, 1907. Read December 16, 1907. Issued separately May 1, 1908.)

This is a report upon the Medusæ collected by the Scottish National Antarctic Expedition during the voyage of the *Scotia* in the years 1902, 1903, and 1904, under the leadership of Dr W. S. Bruce, to whom I am indebted for the opportunity of examining the specimens.

The collection is a small one containing twelve species, but five more species would have probably been added if only the specimens had been in a recognisable condition. Some of the specimens are in excellent condition, and these were mostly taken at the surface, but others are very much damaged. Unfortunately, the damaged specimens are just the ones wanted in good condition, as they mostly come from the Antarctic region and from the stations where the nets were sent down to a great depth. The damage is done in the nets, and other collections which have passed through my hands tell the same tale. It is the rubbing together of the sides of the net that tears the medusæ to pieces. All deep-sea nets should be so constructed that the sides of the nets cannot come together, and also provided with a large can at the end.

The following is a classified list of the species taken on this expedition :—

## Hydromedusæ.

### Anthomedusæ.

*Hippocrene macloviana* (Lesson). Falkland Islands.
*Willia mutabilis*, Browne. Falkland Islands.

### Leptomedusæ.

*Staurophora falklandica*, n. sp. Falkland Islands.
*Phialidium simplex*, Browne. Falkland Islands.

### Trachomedusæ.

*Halicreas papillosum*, Vanhöffen, var. *antarcticum*, nov. Antarctic Ocean.
*Botrynema brucei*, n. g. et n. sp. Antarctic Ocean.

## Scyphomedusæ.

### Coronata.

*Atolla chuni*, Vanhöffen. South Atlantic.
*Atolla wyvillei*, Haeckel. Antarctic Ocean.

### Discophora.

*Pelagia perla* (Slabber). North Atlantic.
*Desmonema chierchiana*, Vanhöffen. Falkland Islands.
*Phacellophora ornata* (Verrill). South Atlantic.
*Aurelia solida*, Browne. North Atlantic.

The principal interest in this collection should be in the specimens taken in the Antarctic Ocean. There is, however, a difference of opinion about the position of the northern boundary line of the Antarctic Ocean, and I consider the Falkland Islands to be outside the boundary line.

It will be seen from the above list that only three species have been taken indisputably within the Antarctic region. *Halicreas papillosum*, var. *antarcticum*, may turn out to be a new species when better specimens have been examined. The new genus *Botrynema* has a well-marked character in the arrangement of the margin of the umbrella into lobes, and the tentacles into groups. *Atolla wyvillei* had already been recorded for the Antarctic. These three species probably live at a considerable depth, and belong to the deep-sea medusæ. Amongst the unrecognisable specimens taken within the Antarctic region are a *Beröe*, and a *Pleurobrachia*, or an allied genus.

During the stay of the *Scotia* in Stanley Harbour, Falkland Islands, a new species of *Staurophora* was secured, very much like the North Atlantic species, and also a fine specimen of *Desmonema chierchiana*, which I have but little doubt has been described under several other names, and is a common Cyaneid of the Magellan Straits and the Falklands. In the large bottle containing the *Desmonema* were some macerated specimens of *Hippocrene macloviana*, *Willia mutabilis*, and *Phialidium simplex*, all of which are common medusæ in Stanley Harbour.

The occurrence of *Phacellophora ornata* in the South Atlantic is of geographical interest, as it has only been previously recorded from Eastport (Maine, U.S.A.), on the North Atlantic coast of America. The finding of *Aurelia solida* at a mid-North Atlantic station is also of interest, because quite recently it was described as a new species from the Indian Ocean.

## HYDROMEDUSÆ.

### ANTHOMEDUSÆ.

#### Family MARGELIDÆ.

*Hippocrene macloviana* (Lesson), 1829.

*Hippocrene macloviana*, Haeckel, 1879, p. 103, Taf. v. fig. 1–2; Browne, 1902, p. 278.

*Station.*—Stanley Harbour, Falkland Islands, 7th January 1903.

Two adult specimens in a macerated condition were found in the bottle containing *Desmonema chierchiana.*

*H. macloviana* is a very common medusa in Stanley Harbour, and has not been recorded from any other locality.

### Family Willidæ.

*Willia mutabilis*, Browne, 1902.

*Willia mutabilis*, Browne, 1902, p. 280.

*Station.*—Stanley Harbour, Falkland Islands, 7th January 1903.

A single specimen in bad condition was found in the bottle containing *Desmonema*. This was one of the new species collected by Mr R. Vallentin in Stanley Harbour during 1898–1899.

## LEPTOMEDUSÆ.

### Family Laodiceidæ, L. Agassiz, 1862.

*Character of the Family.*—Leptomedusæ with cordyli, commonly called sensory clubs, on the margin of the umbrella. (Browne, 1907.)

*Staurophora*, Brandt, 1835.

*Generic Character.*—Laodiceidæ with four radial canals; with a narrow cross-shaped stomach, and mouth extending across the sub-umbrella; with ocelli on the basal bulbs of the tentacles. (Browne, 1907.)

*Staurophora falklandica*, nova species. (Plate I. figs. 1–8.)

*Station.*—Stanley Harbour, Falkland Islands, 7th January 1903.

The collection contains a single specimen, which is in fairly good condition, but rather damaged in places on the margin of the umbrella.

*Description.*—The umbrella is very thin, and measures 90 mm. in diameter when completely flattened out. Its natural shape would probably be something like a shallow watch-glass. The velum is extremely narrow for the size of the umbrella, about 1 mm. in width, and is in an almost rudimentary condition.

The stomach forms a large perradial cross, which extends nearly to the margin of the umbrella, and consequently the true radial canals are very short, about 6 mm. in length. The mouth is of the same length as the stomach, and has its margin arranged in a complicated series of folds. The gonads (male) extend along the whole length of the stomach, forming a close series of deep folds (fig. 5). This folding of the lateral walls of the stomach frequently gives rise to small pockets, which are probably receptacles for the digestion of food.

The principal tentacles (fig. 4) are very numerous (several hundred), closely packed together round the margin of the umbrella. Between every two tentacles there is usually a very small tentacle, somewhat similar to the large tentacles in shape, but not so fine and slender as a typical cirrus.

Between every large and small tentacle there is generally a long cordylus, commonly called a sensory club (figs. 2 and 3). On the inner side of the basal bulbs of the large tentacles, and very close to the velum, there is usually one black ocellus, but it is frequently broken up into two or three smaller pigment spots.

LINKO has found in *Staurophora arctica* minute ectodermal sensory vesicles, which are situated above the velum at its juncture with the umbrella. I have searched for sensory vesicles in this specimen, and have failed to find the slightest trace of one. Transverse sections of the umbrellar margin show a small cavity in the ectoderm in the same position as LINKO's sensory vesicles. This cavity, however, runs through a series of over three hundred thick sections, so that it is not likely to be a sense-organ with otoliths, but it looks more like a breakage in the ectodermal layer.

*Staurophora falklandica* bears a strong resemblance to *S. laciniata*, L. Agassiz, which is found in the North Atlantic, on the coasts of North America and North Europe. The latter species has alternating series of long and short tentacles, but the difference in size is very slight, and both series have ocelli. In the Falkland specimen there is a considerable difference in the size between the two kinds of tentacles (fig. 4). The very small ones are all about the same size and are without ocelli. They have the appearance of rudimentary tentacles. It is rather a risky point, I admit, on which to base the character of a new species, as there is the probability of the small tentacles developing into full-sized tentacles with ocelli.

### Family EUCOPIDÆ.

#### *Phialidium simplex*, Browne, 1902.

*Phialidium simplex*, Browne, 1902, p. 282.

*Station.*—Stanley Harbour, Falkland Islands, 7th January 1903.

A single adult specimen in bad condition of this species was found in the bottle containing *Desmonema chierchiana*.

It was one of the new species in Mr VALLENTIN's collection from Stanley Harbour.

## TRACHOMEDUSÆ.

### Family HALICREIDÆ, Fewkes, 1882.

Vanhöffen, 1902; Maas, 1906.

*Character of Family* (MAAS, 1906).—Trachomedusæ with numerous tentacles differing in size, arranged in a single row; with eight very broad radial canals; with a thick umbrella often provided with outgrowths (with a wide, thin-walled tubular stomach).

## Genus *Halicreas*, Fewkes, 1882.

*Generic Character* (Maas, 1905).—Trachomedusæ with very numerous tentacles (more than fifteen in an octant), which by their unequal sizes show different times of appearing; with a long tubular mouth; with eight perradial outgrowths of jelly near the margin of the umbrella.

### *Halicreas papillosum*, Vanhöffen, var. *antarcticum*, nov.

*Halicreas papillosum*, Vanhöffen, 1902, p. 68, Taf. ix. fig. 7–8, Taf. xi. fig. 30;
Maas, 1905, p. 57, Taf. x. fig. 70, Taf. xi. fig. 71.

*Station* 413, lat. 72° 02′ S., long. 23° 40′ W. Vertical net, 0–1000 fathoms. 15th March 1904.

Two specimens belonging to the genus *Halicreas* were taken at this station, and both are unfortunately in very bad condition.

*Specimen No.* 1.—The umbrella is about 30 mm. in diameter, and is quite flattened out. On the ex-umbrella, at a short distance above the margin, there are eight clusters of papillate processes in the radii of the radial canals. In shape and size these clusters resemble the papillate processes of *Halicreas papillosum* (Vanhöffen, 1902, Taf. ix. fig. 7–8). There are, however, one or two isolated processes in most of the radii, just above the principal cluster.

The stomach has been completely torn out, and not even a trace of it remains. The radial canals have nearly all shared the fate of the stomach, but two have been fairly well preserved from destruction, and are very broad. There are indications of six more canals.

Only the lower parts of the gonads remain on four of the radial canals. The gonads lie in groove-like depressions of the sub-umbrella, and do not extend to the margin of the umbrella. The radial canals and gonads are whitish in formalin. On the surface of the sub-umbrella, somewhere about the periphery of the stomach, there are eight semi-globular projecting lumps of jelly, one between every two radial canals.

The margin of the umbrella is in bad condition, and only the basal stumps of the tentacles, partly embedded in the margin of the umbrella, now remain. The stumps show that the tentacles are very numerous.

*Specimen No.* 2.—This specimen is much smaller than the one described above, and looks like a contorted mass of jelly. It shows the eight clusters of papillate processes near the margin of the umbrella, and the eight semi-globular projections on the sub-umbrella. It is, however, an important specimen, because it shows that the top of the umbrella is capped by a small, low, somewhat spherical lump of jelly, which is studded with about nine small, somewhat conical processes, or tubercles. They closely resemble the marginal processes in shape and size, but are more isolated, being spread over a larger area. In the largest specimen a rather oval cap with about three or more

processes is delineated on the top of the umbrella, which has been squeezed flat by pressure in the net.

The first specimens of this genus were described by FEWKES, 1882, under the name of *Halicreas minimum*. These were taken in the North Atlantic off the coast of the United States, between lat. 38°–39° N. and long. 68°–71° W., and at a considerable depth. As all the specimens were in very bad condition, FEWKES's description and figures are consequently of little scientific value. He succeeded, however, in establishing the genus, but not the species.

It was left to VANHÖFFEN to give the first adequate description of a *Halicreas* (*H. papillosum*), which he illustrated by beautiful figures. His specimens were taken on the voyage of the *Valdivia*, at many stations off the western coast of Africa between the Canary Islands and Cape Town, and the species was again found widely distributed over the warm regions of the Indian Ocean. Its chief habitat is apparently the tropical regions of the Atlantic and Indian Oceans, and although once taken at 300 fathoms, it evidently prefers to live below 500 fathoms. In the Atlantic *H. papillosum* was not found north of lat. 25° N., and its southernmost range in both oceans was not beyond lat. 35° S.

The geographical range of this species is important, and the southern boundary appears to have been fairly well fixed by the *Valdivia*. This ship, after leaving Cape Town, went to Bouvet Island, and then as far south as lat. 64°, off Enderby Land, returning across the Indian Ocean, *via* Kerguelen and New Amsterdam, to Sumatra. Although nets were used at many stations and at great depths, yet this species was not once found south of lat. 35° S.

The *Scotia* specimen was taken in lat. 72°, not far off the Antarctic continent, which is very far outside the geographical range of *H. papillosum*. It is mainly for the sake of geographical distribution that I have decided to establish a new variety, which may attain the rank of a species when better specimens have been obtained. At present the *Scotia* specimens can only be distinguished from those of VANHÖFFEN by the presence of a group of tubercles on the summit of the umbrella.

MAAS has also described and figured *Halicreas papillosum* from specimens obtained by the *Siboga* expedition to the East Indian Archipelago. Some of his specimens have a cone-shaped process on the summit of the umbrella, in which they agree with VANHÖFFEN'S *H. papillosum*; but some have an ordinary plain rounded umbrella, without any ornamentation on the summit. These latter agree with FEWKES' description of *H. minimum*, but FEWKES' specimens were in worse condition than those of the *Scotia*.

VANHÖFFEN has placed in the genus *Halicreas* two other species (*H. glabrum* and *H. rotundatum*) which have not got the marginal groups of tubercles. MAAS' definition of the genus would exclude these two species, as he restricts the genus to species with marginal tubercles. I certainly agree with MAAS in regarding the marginal tubercles as a generic character. It is most probable that more than one

species of *Halicreas* will be ultimately found to possess this character. I cannot call to mind any other kind of medusa possessing tubercles in a similar position, and they are certainly a most useful aid in the identification of specimens in bad condition.

### *Botrynema*, novum genus.

*Generic Character.*—Trachomedusæ with sixteen groups of tentacles (two groups containing many tentacles in a single row in each octant) and eight solitary perradial tentacles (without perradial tubercles or outgrowths of jelly near the margin of the ex-umbrella).

The characteristic feature of this new genus is the arrangement of the tentacles into distinct groups or clusters; hence the generic name. I think less confusion will be produced by introducing a new genus based upon the above character, than by trying to emend an old genus and regarding this character as a specific one. The placing of the new genus *Botrynema* in the family Halicreidæ, as emended by Maas, is provisional. Until better specimens showing the shape of the tentacles and the structure of the sense-organs can be obtained, the position of this genus among the Trachomedusæ must remain doubtful.

### *Botrynema brucei*, nova species. (Plate I. figs. 8–9; Plate II. fig. 1.)

*Station* 301, lat. 64° 48′ S., long. 44° 26′ W. Trawl, 0–2485 fathoms. 13th March 1903.

The collection contains only one specimen which is in fairly good condition, except for the margin of the umbrella.

*Description.*—The umbrella is very thick, about as broad as high, 25 mm., with a conspicuous conical projection on its summit. The velum is very broad. The stomach is circular, about 9 mm. in diameter, and its centre is partly filled with a semi-globular projecting mass of jelly. The mouth is large and circular, owing to the thin wall of stomach being contracted back. There are eight broad radial canals, and a very broad circular canal. The gonads are shield-shaped and occupy the central part of all the radial canals. They are in rather a macerated and torn condition, and have the appearance of immature male gonads.

The tentacles (fig. 1) have all been broken off close to the margin of the umbrella, but their basal ends remain partly embedded in the ex-umbrella. There are eight percanal (perradial) solitary tentacles and sixteen groups of tentacles. The eight solitary percanal tentacles are in a deep groove or furrow, which extends about 2 mm. over the margin of the umbrella. These tentacles are probably directed upwards, and those in the groups directed downwards. *Halicreas papillosum* has eight percanal tentacles which are very much larger (though similar in structure) than the tentacles which line the margin of the umbrella between the radial canals.

The margin of the umbrella of *Botrynema* is divided into sixteen small lobes which are separated by furrows. There are eight percanal furrows, in which are situated the solitary tentacles, and eight inter-canal furrows, smaller in size and without tentacles. Upon each of the sixteen lobes are attached the basal ends of a group of tentacles, about twelve in number, arranged in a single row and in a definite order of growth. The basal ends of the tentacles vary in length and in size, indicating that the tentacles are of different lengths, which is no doubt due to differences in age. In fig. 1 the longest basal ends are nearest to the percanal tentacle, but in some of the other groups the shortest basal end occupies this position. It was in only one of the intervals between the groups of tentacles that very minute basal ends of tentacles were seen. They are indicated in the figure, and are evidently of much later growth than the tentacles on the lobes. *Gossea corynetes* (Petasidæ) has eight distinct groups of tentacles, and in the fully grown adult a few minute tentacles make their appearance, long after the other tentacles, in the vacant space between the groups.

The margin of the umbrella was carefully searched over for sense-organs, and none were seen; but the margin is by no means in good condition, so that the absence of sense-organs is not surprising. The specimen is in formalin, and the colour of the principal organs is whitish. There is no trace of any red or reddish-brown pigment.

I have much pleasure in naming this species after Dr WILLIAM S. BRUCE, the leader of the Scottish National Antarctic Expedition.

## SCYPHOMEDUSÆ.

### CORONATA.

#### Family ATOLLIDÆ.

#### *Atolla chuni*, Vanhöffen, 1902.

*Atolla chuni*, Vanhöffen, 1902, p. 12, Taf. i. fig. 1–2, Taf. v. fig. 26.

*Station* 450, lat. 48° S., long. 9° 50′ W. Trawl, 1332 fathoms. 12th April 1904.

The collection contains one specimen, which evidently got damaged in the trawl. The mouth, stomach, and gonads are partly torn away, but the margin of the umbrella is in fairly good condition.

This species was first found by the *Valdivia* expedition, and has been beautifully figured by VANHÖFFEN. Two specimens were taken by the *Valdivia* between the Cape of Good Hope and Bouvet Island (lat. 42° S., long. 14° E.) in a vertical net at 1500 metres (821 fathoms), in the Antarctic current with a temperature of 0°·8 C.

*Atolla chuni* is distinguished from the other species of the genus by the presence

of warts (*Gallertperlen*) on the marginal lobes. In the *Scotia* specimen the warts are quite conspicuous upon the lobes. Some of the lobes have nine warts (four on each side and one in the middle), agreeing in number, position, and size with VANHÖFFEN's description. Many lobes, however, have only seven warts (three on each side and one in the middle), and as the two smaller uppermost warts are the missing ones, these lobes are probably at an earlier stage in development. The central wart was missing in two lobes—perhaps an instance of variation.

There are twenty-four tentacles and twenty-four sense-organs. The gonads are completely torn away in places, and only two perfect and two imperfect sacs remain. There is sufficient evidence to show that the genital sacs form very nearly a complete ring. Two of the sacs are close enough to touch each other, and others show only a very slight separation.

*Measurements.*—(The specimen is rather flattened out.) Diameter of the central disc, 23 mm. Diameter of the muscle-band, 35 mm. Diameter of the stomach, 16 mm. Length and width of pedalia, 3·5 mm.

## *Atolla wyvillei*, Haeckel, 1880.

*Atolla wyvillei*, Haeckel, 1880, p. 488; Haeckel, 1881, p. 113, pl. xxix.; Vanhöffen, 1902, p. 13, Taf. v. fig. 22.

*Station* 413, lat. 72° 02′ S., long. 23° 40′ W. Vertical net, 0–1000 fathoms. 15th March 1904.

At this station was taken an *Atolla* which is in very bad condition. Its stomach and gonads are completely gone, and the umbrella is flattened out.

The periphery of the central disc is distinctly divided into large lobes, and the radial furrows separating the lobes are rather broad. The furrows resemble those in VANHÖFFEN's figure of *Atolla wyvillei* much more than those in the one he gives of *A. verrilli*. It is upon the shape of the furrows that I have decided to call the specimen *A. wyvillei* rather than *A. verrilli*. There are twenty-two tentacles, and the marginal lobes are without warts. The pedalia have a slight longitudinal furrow. As the diameter of the muscle-band is only 25 mm., the specimen is about half-grown.

*Atolla wyvillei* was first found by the *Challenger* expedition at the depth of about 2000 fathoms. Three specimens were taken about midway between the Kerguelen Islands and Melbourne (lat. 53° S., long. 108° E.), and two specimens in the South Atlantic Ocean off the coast of Patagonia (lat. 42° S., long. 56° W.). The *Valdivia* expedition secured a specimen south-east of Bouvet Island (lat. 56° S., long. 14° E.) in a vertical net down to 1500 metres (821 fathoms), and another specimen off Kemp Land (lat. 63° S., long. 57° E.) in a dredge down to 4600 metres (2517 fathoms).

## DISCOPHORA.

### Family Pelagiidæ.

*Pelagia perla* (Slabber), 1775.

*Station* 542, lat. 37° 56′ N., long. 29° 11′ W. 4th July 1904.

*Station* 543, Fayal Harbour, Azores. Surface. 5th July 1904.

*Station* 544, lat. 39° 15′ N., long. 26° 55′ W. (north of the Azores). Surface. 7th July 1904.

Fourteen specimens were taken in Fayal Harbour. The smallest is about 50 mm. in diameter, and the largest about 75 mm. The umbrella is about twice as broad as high, and externally covered with large elliptical warts. The marginal lobes are quadrilateral, with rounded corners, a little broader than long. The oral arms are about twice the length of the radius of the umbrella, and the œsophagus about two-thirds the length of the radius.

Eighteen specimens were collected at the station north of the Azores. They are all young stages, about 20–30 mm. in diameter, and have roundish warts on the exumbrella. At Station 542 a single specimen in very bad condition was taken.

There is probably only one species of *Pelagia* in the North Atlantic, though six have been described.

### Family Cyaneidæ.

*Desmonema*, L. Agassiz, 1862.

This genus was established by L. Agassiz for the reception of *Chrysaora gaudichaudi*, Lesson, which was first discovered during the voyage of the *Coquille* in Soledad Bay, Falkland Islands, and also near Cape Horn. At the same time Agassiz made another new genus called *Couthouyia*, of which only a very brief account was given. Haeckel emended the definition of the genus *Desmonema* so as to include *Couthouyia*, and added three species, namely, *Couthouyia pendula*, L. Agassiz; *Cyanea imporcata*, Norman; and a new species called *Desmonema annasethe*. According to Haeckel's definition, *Desmonema* differs from *Cyanea* in having the tentacles arranged in a single row instead of in several rows.

Vanhöffen a little later also emended the genus, and rejected Haeckel's distinction as to the arrangement of the tentacles, on the ground that *Cyanea* passes through a stage with the tentacles arranged in a single row. Vanhöffen's definition of the genus *Desmonema* is based upon Agassiz's brief description of *Couthouyia pendula*, and the genus therefore should have been called *Couthouyia*. According to Vanhöffen, *Desmonema* differs from *Cyanea* in possessing twenty-four marginal lobes. In *Desmonema* the tentacular lobes are not divided as in *Cyanea*. The gonads are shorter and do not hang down so far as those of *Cyanea*, and the oral arms taper from a broad

base. VANHÖFFEN places three species in the genus, the two old ones, *D. pendula* from Tierra del Fuego, *D. gaudichaudi* from the Falklands and from near Cape Horn, and a new species called *D. chierchiana* found at Punta Arenas in the Straits of Magellan. This last species has been fully described and well figured, but I am able to add a further account after the examination of five specimens in different stages of development found in Stanley Harbour, Falkland Islands. It will be noticed that the above three species are inhabiting the same region, and I have but little doubt that they all belong to one species, which, in accordance with the law of priority, should be called *Desmonema gaudichaudi* (Lesson).

The description of *Chrysaora gaudichaudi* by LESSON is incomplete, and is based upon an abnormal specimen with twelve groups of tentacles instead of the normal eight. Consequently the shape and size of the marginal lobes would differ from those of the normal type. AGASSIZ's description of *Couthouyia pendula* is practically a generic one, but he does state that the oral arms are of an extraordinary length.

VANHÖFFEN points out that *Desmonema chierchiana* is distinguished from *D. gaudichaudi* by shorter oral arms. The largest specimen in the *Scotia* collection shows that *D. chierchiana* has much longer arms than those mentioned by VANHÖFFEN. The length and size of the oral arms are of little use for a specific character, on account of their great power of expansion and contraction. VANHÖFFEN also points out that the shape and size of the marginal lobes of *D. chierchiana* differ from those of *D. gaudichaudi*. It must be remembered that LESSON's specimen was an abnormal one. The marginal lobes of the *Scotia* specimens are not quite like those of VANHÖFFEN's Punta Arenas specimens, the difference being probably due to variation and not to a different geographical race.

VANHÖFFEN lays a certain amount of stress on the gonads of *Desmonema* being smaller than those of *Cyanea*, and not hanging down so far. The largest specimen in the *Scotia* collection has much larger gonads than VANHÖFFEN's specimen, and they are just like the gonads of *Cyanea capillata*.

I rather think that the specific character of *D. chierchiana* lies in the arrangement of the tentacles in practically a straight row, adjacent to the distal edge of the circular muscles. Concomitant with the straight row of tentacles are the undivided tentacular lobes, and the absence of radial muscles in the marginal lobes. The tapering of the oral arms may also come in as a useful aid for the determination of the species. The ultimate fate of *Desmonema* as an independent genus depends upon the revision of the genera and species of the Cyaneidæ. MAAS (1904) has also commented upon the relationship of *Desmonema* and *Cyanea*, and the necessity for a revision of the species.

*Desmonema chierchiana*, Vanhöffen, 1888. (Plate II. fig. 2.)

*Desmonema chierchiana*, Vanhöffen, 1888, p. 17, Taf. i. fig. 4.
? *Chrysaora gaudichaudi*, Lesson, 1830, p. 114, pl. xiii. fig. 1.
? *Desmonema gaudichaudi*, L. Agassiz, 1862, vol. iv. p. 166.
? *Desmonema gaudichaudi*, Haeckel, 1880, p. 527.
? *Couthouyia pendula*, L. Agassiz, 1862, vol. iv. p. 118, p. 163.
? *Desmonema pendula*, Haeckel, 1880, p. 528.

*Station.*—Stanley Harbour, Falkland Islands, 7th January 1903.

The *Scotia* brought home three specimens, the largest of which is in splendid condition, but the other two are not quite perfect. The large collection of medusæ made by Mr Rupert Vallentin in Stanley Harbour during the summer of 1898–1899 is still in my possession, and it contains two early stages of this species in excellent condition. At the time when I examined Mr Vallentin's collection I was unable to identify these young stages, as they were just too young to show clearly the generic characters. By the aid of the *Scotia* specimens I have now been able to identify them, and the five specimens form a nice series showing different stages in development.

*Specimen A* (Vallentin Coll.).—This specimen is the youngest of the series, and its development has not proceeded very far beyond the *Ephyra* stage.

The umbrella is very thin and flat, measuring about 14 mm. in diameter. The exumbrella has scattered over its surface numerous small clusters of nematocysts, which are most prominent and conspicuous on the marginal lobes. The stomach is circular, about 9 mm. in diameter, and has sixteen radiating pouches which are separated from each other by radial septa. Eight of the pouches are opposite sense-organs, and eight opposite the groups of tentacles. Within the stomach are four interradial bundles of gastric filaments. From the mouth hang down four oral arms, which are a little longer than the radius of the umbrella. They have the appearance of four large lips folded along the centre. Their external surface is closely covered with small warts containing nematocysts.

There are eight adradial groups of tentacles, each group containing one long tentacle and four to six minute tentacles or tentacular buds. The presence of one long tentacle in each group indicates that in an earlier stage only eight tentacles are present. The tentacles are within the margin of the umbrella, adjacent to the distal edge of the gastral pouches. There are eight tentaculocysts (rhopalia), four perradial and four interradial.

The margin of the umbrella is divided into sixteen lobes or lappets by eight deep clefts leading to the sense-organs, and by eight clefts, not quite so deep, which occur in the middle of the tentacular lobes (the lobes opposite the groups of tentacles). At this stage, however, each marginal lobe is composed of one ocular and half a tentacular lobe. Later on this cleft in the middle of the tentacular lobes becomes obliterated. The marginal lobes have a definite series of canals connected with the pouches of the stomach. The canal system will be described in the next stage.

*Specimen B* (VALLENTIN Coll.).—The umbrella is fairly thin and flat, measuring about 25 mm. in diameter, and is very pellucid in formalin.

The stomach is about 15 mm. in diameter, with sixteen radial pouches. The tentacular pouches are a little broader than the ocular ones. The oral arms are about twice as long as the radius of the umbrella.

The tentacles show an increase in number and in size. In each group the central tentacle is very conspicuous by its great length (fig. 2). It is at least six times as long as the other tentacles. Each group contains about three to six tentacles and about six tentacular buds.

The cleft in the middle of the tentacular lobe has nearly disappeared (fig. 2), and the ocular lobes are just marked off by a slight incurving of the margin. Each ocular lobe has a broad canal which gives off a number of short lateral branches, which in this stage are just beginning to develop. The tentacular lobes have a number of canals, one between every two tentacles. These canals in the later stages have each a series of bifurcations.

*Specimen C* (*Scotia* Coll.).—The umbrella is moderately curved and is fairly thick, measuring 50 mm. in width and 20 mm. in height.

The stomach is circular, about 25 mm. in diameter, with sixteen radiating pouches. The width of the tentacular pouches at their distal end is about 10 mm., and the ocular pouches about 7 mm. The oral arms are in a damaged condition. The width between the pillars of the arms, measured across the oval where the gonads are just beginning to show, is 11 mm., and the width of the pillar is 3 mm. at its narrowest point.

There are eight groups of tentacles arranged in a straight single row. Each group consists of twelve to fifteen tentacles, with the largest in the middle. The large tentacles are all in a broken condition.

The cleft in the middle of the tentacular lobes has practically disappeared. The ocular lobes are slightly more prominent, projecting further out than the tentacular lobes. The canal system is of the same pattern as in specimen B, but the branches have more bifurcations.

*Specimen D.*—The umbrella is fairly thick, about 80 mm. in width and 40 mm. in height. Clusters of nematocysts are closely scattered over the ex-umbrella and the marginal lobes, but the warts are absent, so that the surface looks quite smooth.

The stomach measures about 35 mm. in diameter. The width of the tentacular pouches at the distal end is about 18 mm., and the ocular about 12 mm. This specimen is in a damaged condition, having lost its oral arms, gonads, and tentacles. The distance between the pillars of the oral arms is about 15 mm. There are indications of twelve to fourteen tentacles in each of the eight groups.

The ocular and tentacular lobes are united into one large lobe with an even margin. The marginal distinction between the lobes has become obliterated, and the medusa has the appearance of possessing eight broad marginal lobes which are separated from each other by the deep ocular clefts. But owing to the incurving of the margin of the

umbrella its margin appears to be deeply lobated. Upon the periphery of the exumbrella there are sixteen deep radial furrows, in line with the sixteen radial septa which divide the pouches of the stomach. It is along these furrows that the folding takes place, dividing the margin into sixteen broad folds, each of which is again subdivided by the eight ocular clefts, and by an indentation in the middle of the tentacular lobes. On straightening out the margin of the umbrella all these folds disappear, and one then sees the true lobation of the margin.

*Specimen E.*—This specimen is the largest in the *Scotia* collection, and as it is in excellent condition full details are given.

The umbrella is rather flat, and has probably flattened out in the jar owing to the pliability of the jelly. It measures about 160 mm. in diameter with the marginal lobes folded inwards. For the size of the umbrella the jelly is not very thick.

The stomach is circular in outline, about 75 mm. in diameter, with sixteen radial pouches. The tentacular pouches are 35–40 mm. in width at their distal margin, and the ocular about 25–30 mm. The circular muscle-bands of the sub-umbrella are upon the lower wall of the pouches, and are separated radially by sixteen furrows which correspond in position to the septa of the gastral pouches. I have not been able to find any radial muscle-bands on the sub-umbrella or the marginal lobes.

The four oral arms are about 350 mm. in length, and are probably capable of extending to a much greater length. Along the whole length of each arm runs a double frill. These frills are very broad near the mouth and gradually decrease in width towards the distal end of the arms, and give to the arms a long, slender appearance. The width of the pillars of the arms is 7–8 mm. across the narrowest part.

The four gonads are similar in position and shape to those of *Cyanea capillata*. They hang down in clusters from between the bases of the oral arms, and are much larger than the gonads of the specimen figured by VANHÖFFEN. As the medusa lies flat in the dish the gonads extend about half way across the circular muscles. The ova are quite small and immature, so that in a fully ripe condition the gonads should be much larger in size. The genital openings between the oral arms are oval in shape and measure nearly 40 mm. in length.

There are eight groups of tentacles arranged in a straight single row, adjacent to the outer edge of the circular muscles. The largest tentacles are in the middle of the group and the smallest on either side. They are like long threads with a dark reddish endoderm, and externally covered closely with roundish warts containing nematocysts. The number of tentacles in each group is as follows: 20, 21, 19, 17, 18, 20, 21, 19.

The eight sense-organs are quite simple in their construction. The tentaculocyst in the early stages lies in a rather broad U-shaped groove, which is partly covered on the sub-umbrella side by the margins of the two ocular lobes. In the adult stage, owing to the increase in the size of the ocular lobes, the groove is longer and is completely covered by the ocular lobes. A canal from the pouch of the stomach runs in the roof of the groove, and at its distal end is situated a small tentaculocyst, about twice

as long as broad, containing concretions. On the wall of this canal near the tentaculocyst a small roundish swelling is present in the earlier stages, and a long ridge-like swelling in the adult. It is probably a sensory pad.

The medusa as it lies on its back in a basin, with the margin of the umbrella folded inwards, shows very clearly the sixteen radial furrows on the periphery of the exumbrella. These furrows are lines of weakness, for they reduce the thickness of the marginal jelly. In two places the ocular lobe is completely isolated from the tentacular lobe, the tearing asunder taking place along the furrow. The folding of the incurved margin is similar to that described for specimen D.

The tentacular lobes measure 55 mm. in breadth, and are about two and a half times as broad as the ocular lobes. Their length is about 30 mm. In this specimen the length of the tentacular and ocular lobes is about the same. In VANHÖFFEN'S specimen the ocular lobes are a little shorter than the tentacular. In most of the octants there is no indentation between the tentacular and ocular lobes; an even margin extends from one ocular cleft to another. But in two places there are natural indentations between the ocular and tentacular lobes, very much like the indentations drawn by VANHÖFFEN. Evidently there is a fair range of variation in the shape and size of the marginal lobes, and taken by themselves they are not a specific character. The marginal lobes and the surface of the ex-umbrella are quite smooth. Apparently the warts conspicuous on the lobes in the early stages disappear before the medusa reaches the adult state.

The arrangement of the canals in the marginal lobes is similar to that in the earlier stages, but there are more bifurcations. The canal system has been well illustrated in VANHÖFFEN'S figure.

In Mr VALLENTIN'S manuscript notes I have found several references to *Desmonema* in Stanley Harbour, from November 1898 to February 1899. During November large and small specimens were very abundant, the largest being about 1 foot (300 mm.) in diameter. At the end of December specimens up to 2 feet (600 mm.) in diameter were abundant. Records show that large specimens were present in considerable numbers during January and February. On 6th February thousands were stranded on the shore after a strong wind.

## Family ULMARIDÆ.

### *Phacellophora ornata* (Verrill, 1869). (Plate II. figs. 3–4).

*Callinema ornata*, Verrill, 1869, p. 116.
*Callinema ornata*, Fewkes, 1888, p. 234, pl. vi.
*Phacellophora ornata*, Haeckel, 1880, p. 643.
*Phacellophora ornata*, Vanhöffen, 1906, p. 59, figs. 25–26.

*Station* 98, lat. 34° 2′ S., long. 49° 7′ W. Surface. 28th December 1902.

A single specimen was taken at this station, which is about five degrees east of Montevideo. It is unfortunately damaged, having completely lost the oral arms.

In the *Voyage of the Scotia*, a book which gives an interesting and popular account of the work done by the Scottish National Antarctic Expedition, there is an allusion to this medusa: "On the 28th, in 33° 51′ S., 48° 48′ W., we crossed a great yellow band of gelatinous scum stretching from horizon to horizon. It proved to consist of microscopic algæ (Desmidæ) closely allied to the diatoms, and in the scum were numbers of Portuguese men-of-war (*Physalia*), Jelly-fish (*Aurelia*), Ctenophores, and other organisms." The specimen was labelled *Aurelia* sp.

*Description.*—The umbrella has flattened out, and as it lies in the dish it is about five times as broad as high. The diameter, measured across to the circular canal, is about 120 mm. The central portion of the ex-umbrella is slightly raised and is covered with small warts, which are quite visible to the naked eye. The periphery of the umbrella is quite smooth. The base of the stomach is small for the size of the umbrella, measuring only 30 mm. in diameter. The oral arms have disappeared, and only broken stumps remain.

From the stomach to the circular canal run forty-two broad radial canals. The canals in the radii of the sense-organs are branched; the branching is rather irregular, and there is a tendency to anastomosis (fig. 3). The canals in the radii of the tentacles are unbranched, with somewhat irregular outlines.

The margin of the umbrella is not quite perfect, but nine sense-organs are present, and the number of branched radial canals indicates that two sense-organs are missing. The tentacles are arranged in a single row along the outer edge of the circular canal. The row is broken by the sense-organs so that groups are formed.

The character of the genus *Phacellophora* is the presence of sixteen sense-organs, by which it is distinguished from *Sthenonia* with eight sense-organs. The *Scotia* specimen has eleven sense-organs and eleven groups of tentacles, and it is evident from the irregular distribution of the sense-organs that the specimen is an abnormal one. In two places on the margin the sense-organs are very close together, with just a few tentacles between them.

There are twenty tentacles in the largest group, and a very small tentacular bud lies between every two tentacles. The tentacles are all about the same size and have a well-marked character. They have the appearance of long, tapering threads of clear jelly, with a thin whitish line along the outer side. On applying higher magnification one sees that the tentacle has a canal running along its whole length. This canal in the basal portion of the tentacle is very large, forming a large hollow cavity; but it quickly decreases in size until it becomes a very tiny tube, which is perhaps solid towards the distal end, running not in the centre of the tentacle, but close against the outer side (fig. 4). It is only the basal portion of the tentacle that is really hollow, and the canal is a rudiment of an axial endodermal cavity. Along the outer side of the tentacle runs a double row of warts, which are loaded with nematocysts. There are no muscle-fibres visible in the tentacles.

The ocular lobes (fig. 3) on the margin of the umbrella are thick, being flat on the

inner side and rounded on the ex-umbrellar side. They are about 12 mm. in length and 6 mm. in width, having the outer edge with rounded corners, and are separated from the tentacular lobe by a slight marginal cleft. Along the centre of each ocular lobe runs an unbranched canal.

The tentacular lobes are about as long as the ocular lobes, and have an undulating margin. These lobes correspond in number and width with the groups of tentacles. Each lobe has a few isolated canals which are in connection with the circular canal. Some of these canals are slightly bifurcated at the distal end.

This specimen agrees very well with FEWKES' description and figures of *Callinema ornata* so far as the canal system, sense-organs, tentacles, and marginal lobes are concerned. *Phacellophora ornata* up till now has only been taken in one locality, namely, at Eastport, on the coast of Maine, U.S., in the North Atlantic. VERRILL obtained three specimens, and many years later FEWKES secured another.

## *Aurelia solida*, Browne.

*Aurelia solida*, Browne, 1905, p. 960, pl. xciv.

*Station* 539, lat. 33° 53′ N., long. 32° 27′ W. Surface. 1st July 1904.

Four specimens were taken at this station, which is about 15 degrees west of Madeira. Two are in very good condition, and two have a dilapidated umbrellar margin. My original description of *Aurelia solida* was based upon a single specimen obtained by Mr STANLEY GARDINER during his expedition to the Maldive and Laccadive Archipelagoes. I was certainly surprised to find this species from a mid-North Atlantic station in the *Scotia* collection. The occurrence of this *Aurelia* in the Indian Ocean and the North Atlantic shows a very wide geographical range, and it is most probable that the species has been taken long ago and recorded under another name. But none of the descriptions and figures of the numerous species of *Aurelia* show the characters of this medusa. It is certainly not *Aurelia aurita*, neither can it be regarded as a variety of that species.

*Description.*—The umbrella is hemispherical, about twice as broad as high, and thick. The four specimens are about the same size, 55–60 mm. in width, and smaller than the Maldive specimen, which measured 80 mm. in width. The ex-umbrella is covered with small circular clusters of nematocysts.

The mouth is cross-shaped and formed by four thick, somewhat triangular segments, which are about 20 mm. in length. The four segments are interradial and separated from one another. The mouth has the appearance of a cone-shaped lump of jelly cut longitudinally into four equal segments, and the four pieces placed together again. Along the outer edge of each segment runs a short frill, which at the base grows out to form the oral arm, which extends a little way beyond the margin of the umbrella.

The radial canals show a certain amount of variation, especially in the interradial series, and a slight amount of anastomosis takes place near the margin of the umbrella.

The sense-organs are exactly like those described in the Maldive specimen. The tentaculocysts are at right angles to the margin of the umbrella, pointing towards the ex-umbrella, and stand in a kind of alcove which is at the end of a deep groove open on the dorsal or ex-umbrellar side. It is by the position and structure of the sense-organ that this species can at once be distinguished from *Aurelia aurita*.

The subgenital cavities are nearly circular, and have a fairly thick covering, with a small circular aperture about 2 mm. in diameter. They are similar in shape to those of the Maldive specimen, but are not so prominent and have not such a thick external wall. The gonads form oval or horse-shoe-shaped bands. They have not reached maturity.

Jelly-fishes in an unrecognisable condition were taken at the following stations:—

*Station* 325, Scotia Bay, South Orkneys, 25th March 1903. "Fragments of a *Beröe*."

*Station* 414, lat. 71° 50′ S., long. 23° 30′ W.; 0–1000 fathoms. Vertical net. One Trachomedusa. Fragments of the umbrella of a Scyphomedusa. One specimen of a large *Pleurobrachia*?

*Station* 415, lat. 71° 28′ S., long. 22° 32′ W.; 0–2338 fathoms. A lump of jelly found in a sounding-tube.

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## EXPLANATION OF PLATES.

### PLATE I.

*Staurophora falklandica*, n. sp.

Fig. 1. Oral view. Natural size.

Fig. 2. Cordylus partly contracted. × 140.

Fig. 3. Cordylus expanded. × 140.

Fig. 4. Margin of the umbrella, showing the tentacles and cordyli. Inner side. × 25. *cc.*, circular canal; *oc.*, ocellus; *sc.*, cordylus; $T^2$., rudimentary tentacle; *v.*, velum.

Fig. 5. Inner side of the wall of the stomach with gonads. × 10. *g.*, gonads; *m.*, margin of the mouth.

Fig. 6. Lateral view of the base of a tentacle. × 25.

Fig. 7. Basal bulb of a tentacle. Outer side. × 25. *t.r.*, the spur or root of the tentacle.

Fig. 8. *Botrynema brucei*, n. g., n. sp. Lateral view. The margin of the umbrella is curled inwards. × 2.

Fig. 9. *Botrynema brucei.* Diagram showing the position of the gonads.
*cc.*, circular canal; *g*, gonads; *m.*, margin of mouth; *r.*, radial canal; *st.*, stomach.

### PLATE II.

Fig. 1. *Botrynema brucei.* A sketch showing the arrangement of the tentacles on the margin of the umbrella. The velum is omitted; its position is below the tentacles. Aboral view. × 9. *per.*, percanal (perradial) radius; *inter.*, intercanal radius; *p.t.*, percanal tentacle.

Fig. 2. *Desmonema chierchiana*, Vanhöffen. A portion of the sub-umbrella showing the arrangement of the circular muscles, tentacles, sense-organs, and marginal lobes in a young stage. × 3. *c.m.*, circular muscles; *oc.c.*, canal of the ocular lobe; *oc.l.*, ocular lobe; *r.*, tentaculocyst (rhopalium); *spt.*, septum dividing the pouches of the stomach; *t.c.*, canal of the tentacular lobe; *t.l.*, tentacular lobe.

Fig. 3. *Phacellophora ornata* (Verrill). A portion of the sub-umbrella showing the arrangement of the radial canals, sense-organs, and tentacles. Natural size. *cc.*, circular canal; *oc.c.*, canal of the ocular lobe; *oc.l.*, ocular lobe; *r.*, tentaculocyst; *r.c.*, radial canals; *s.*, stomach; *t.*, tentacles (cut off at base); *t.c.*, canal of the tentacular lobe; *t.l.*, tentacular lobe.

Fig. 4. *Phacellophora ornata.* Portion of a tentacle, showing the arrangement of the nematocysts. *e.*, endodermal canal; *n.*, nematocysts.

## *Addendum.*

On the sub-umbrella and on the gonads of the large *Desmonema chierchiana* many amphipods were found. Mrs E. W. SEXTON of Plymouth kindly undertook their identification, and informs me that they are *Hyperia gaudichaudi* (H. Milne-Edwards). Most of the specimens were immature, but adult males and females were present. *Hyperia gaudichaudi* has been taken off the coast of Chile, and was present in the Antarctic collections made by the *Southern Cross* and by the *Discovery*.

Fig. 2.

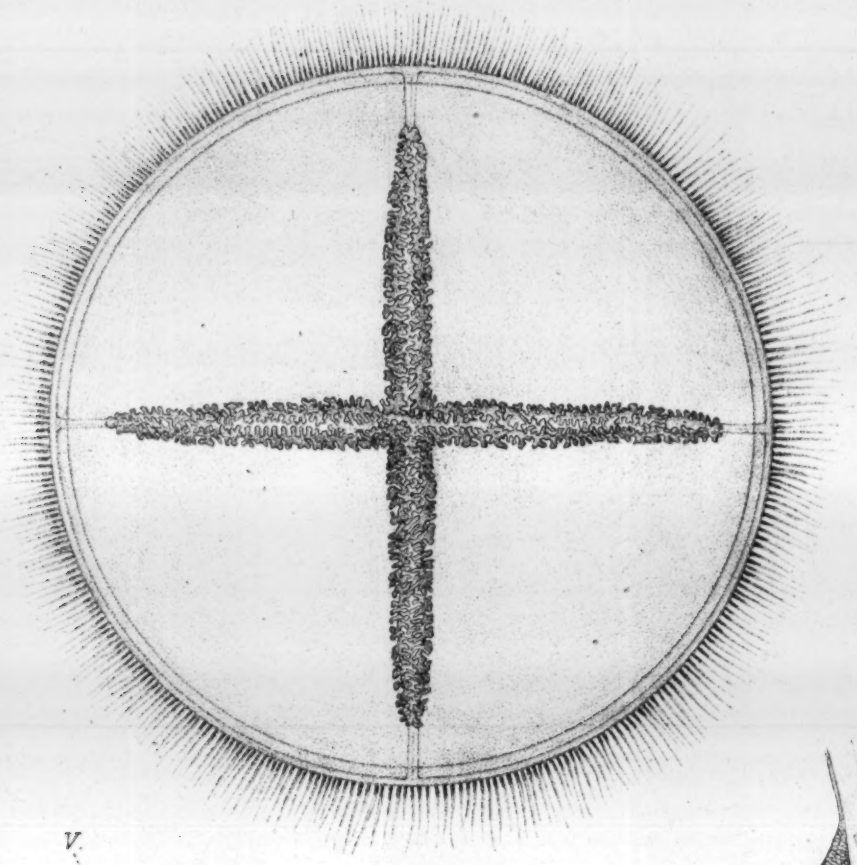

Fig. 1.

Fig. 3.

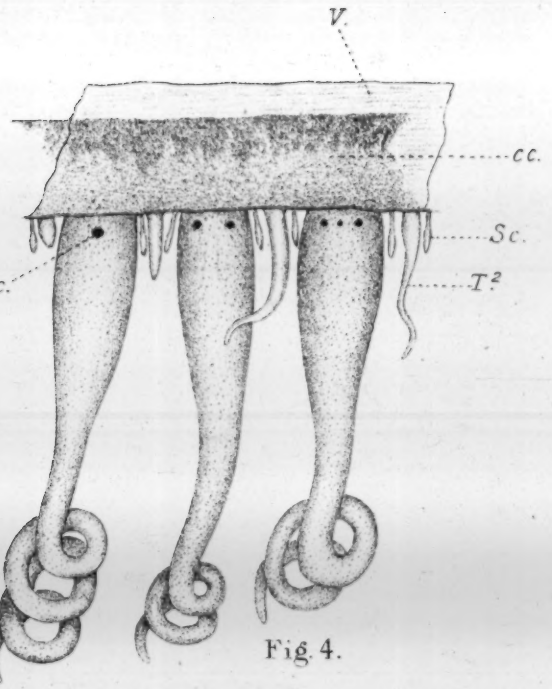


Fig. 4.

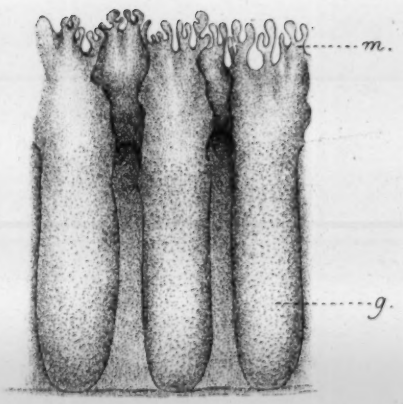


Fig. 5.

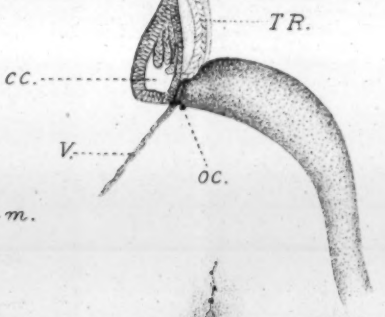


Fig. 6.

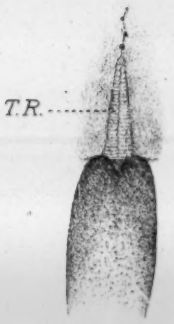


Fig. 7.

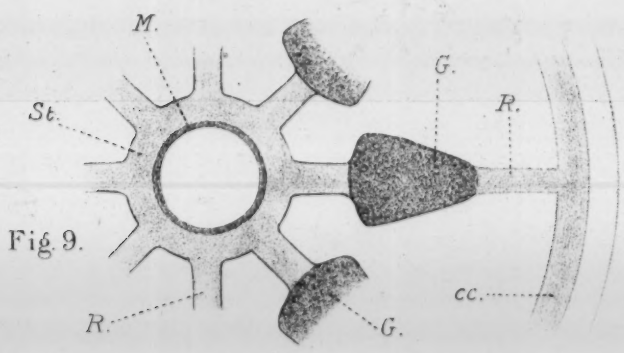


Fig. 9.

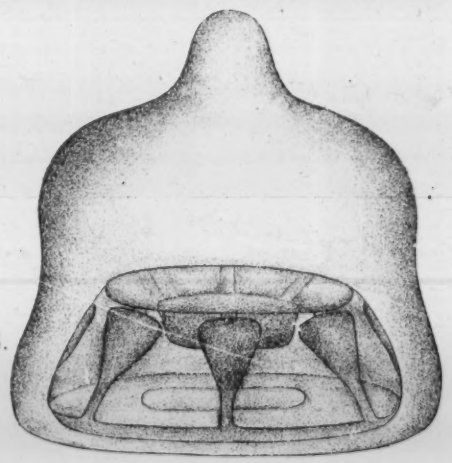

Fig. 8.



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E. T. Browne: Medusæ of the Scottish National Antarctic Expedition — Plate II.

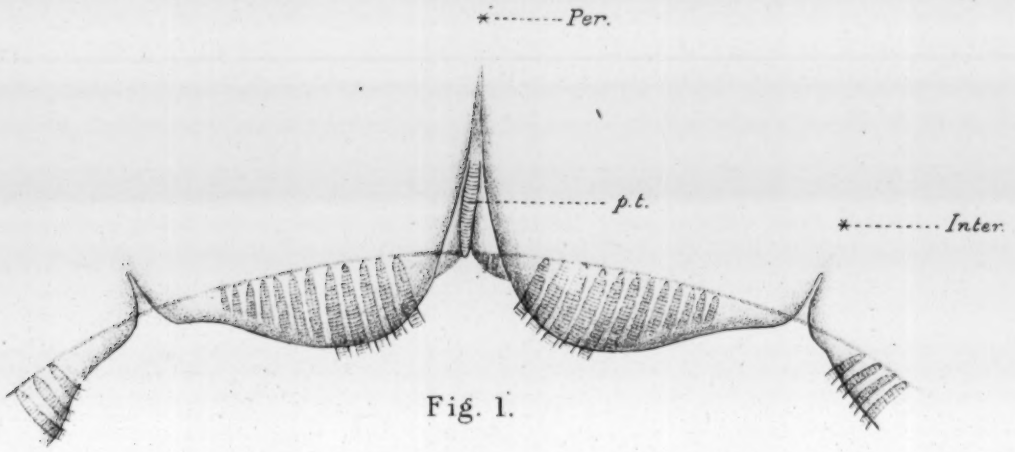


Fig. 1.

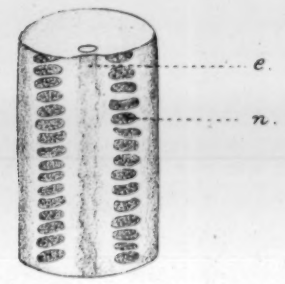


Fig. 4.

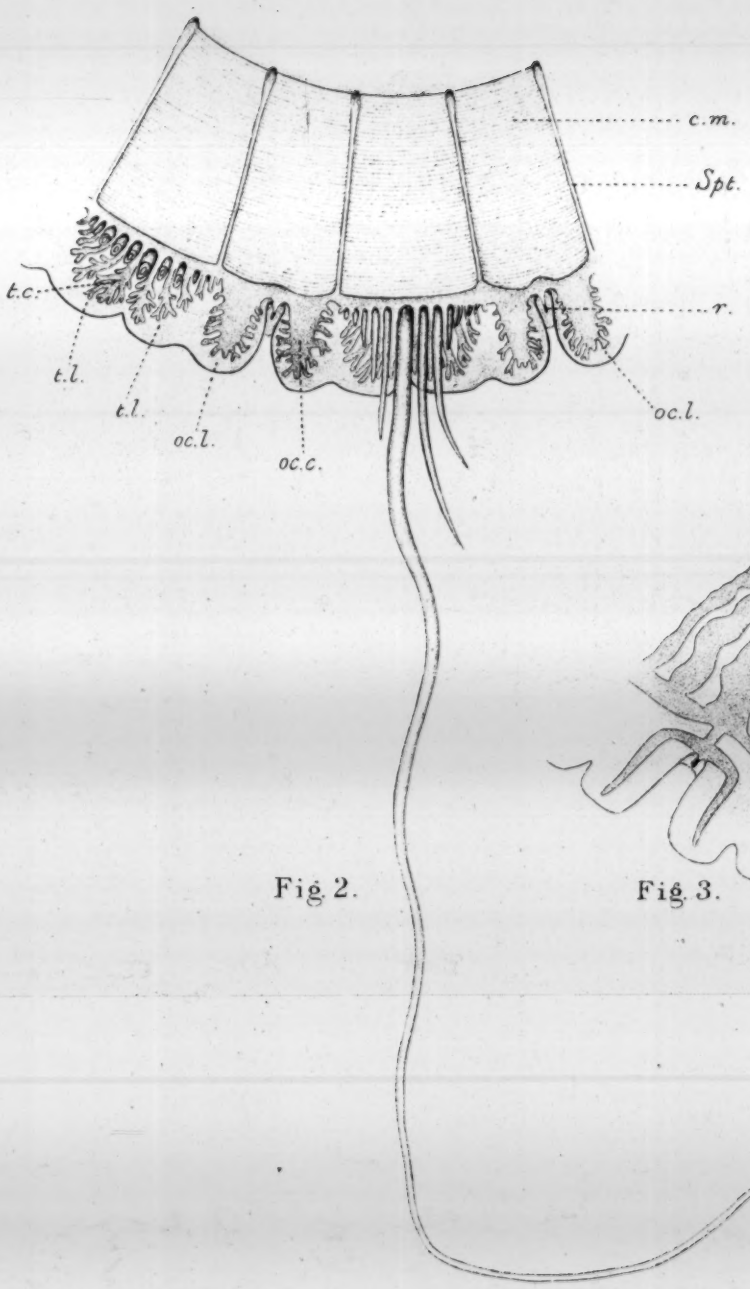


Fig. 2.

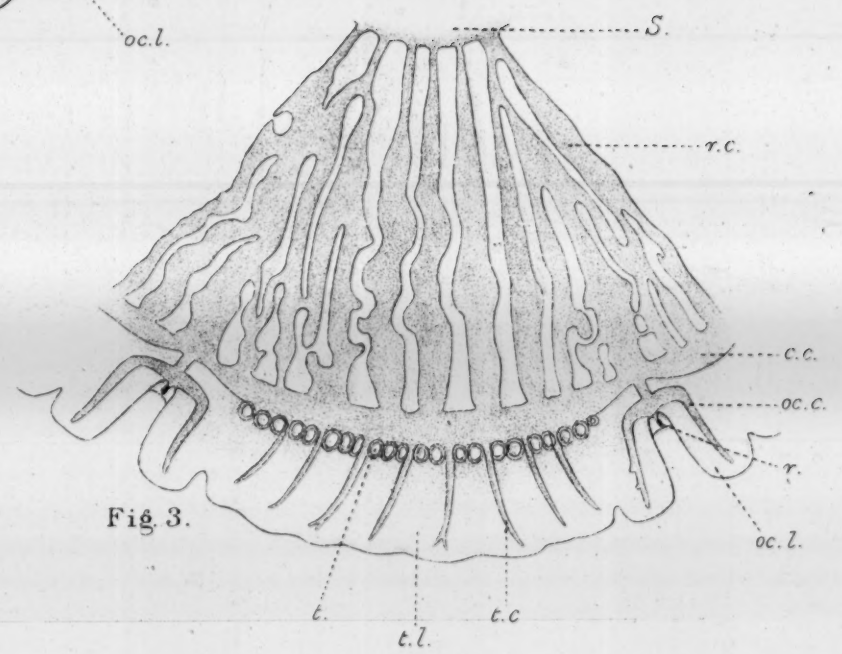


Fig. 3.

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# XI.—On $q$-Functions and a certain Difference Operator. By the Rev. F. H. Jackson, M.A. *Communicated by* Professor CHRYSTAL.

(MS. received January 16, 1908. Read February 17, 1908. Issued separately April 21, 1908.)

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## Part I.

### Introduction.

In this paper my object is, primarily, to investigate the properties of a certain operative symbol $\Delta_x^n$, which appears to be of great utility in discussing $q$-functions. The first part of the paper will consist of an investigation into the various forms of

$$\Delta_x^n\{\phi(x)\},$$

and the nature of the inverse operations symbolised by $\Delta^{-n}$. With certain restrictions as to continuity, etc., $\phi(x)$ will denote an arbitrary function of $x$. In the second part of the paper such products as

$$(1+a_1x+a_2x^2+\ldots+a_nx^n)(1+a_1qx+a_2q^2x^2+\ldots+a_nq^nx^n)(1+a_1q^2x+\ldots+a_nq^{2n}x^n)\ldots\ldots,$$

$$\frac{(1+ax)\left(1+\frac{ax}{q}\right)^2\left(1+\frac{ax}{q^2}\right)^3\ldots\ldots}{(1+bx)\left(1+\frac{bx}{q}\right)^2\left(1+\frac{bx}{q^2}\right)^3\ldots\ldots},$$

$$\frac{(1+2qx\cos\theta+q^2x^2)(1+2q^2x\cos\theta+q^4x^2)^2(1+2q^3x\cos\theta+q^6x^2)^3\ldots\ldots}{(1+2qy\cos\theta+q^2y^2)(1+2q^2y\cos\theta+q^4y^2)^2(1+2q^3y\cos\theta+q^6y^2)^3\ldots\ldots},$$
$$=\lambda_0(x,y)+\lambda_1(x,y)\cos\theta+\lambda_2(x,y)\cos 2\theta+\ldots\ldots,$$

will be discussed, and relations found between the coefficients $\lambda(x, y)$, and the $q$ generalisations of Bessel's Functions denoted by the symbols $J_{[n]}(x)$, $\mathfrak{J}_{[n]}(x)$, in previous papers.*

In the third section of the paper certain special $\Delta$-equations will be discussed in connection with their limiting forms as linear differential equations.

In the appendix to Chapter ii. of Heine's *Kugelfunctionen*† there is given a discussion of the special $q$-function $\phi(a, b, c, q, x)$ analogous to the Hypergeometric series $F(a, b, c, x)$. Heine makes use of a difference symbol $\Delta$, which he defines by the equation

$$\Delta\phi(a,b,c,q,x)=\phi(a,b,c,q,qx)-\phi(a,b,c,q,x).$$

It is obvious that the repetition of the operation symbolised by $\Delta$ gives us

$$\Delta^n\Phi(x)=\Phi(q^nx)-n\Phi(q^{n-1}x)+\frac{n(n-1)}{2!}\Phi(q^{n-2}x)+\ldots\ldots(-1)^n\Phi(x).$$

Now, in $q$ series, such coefficients as the Binomial coefficients do not usually appear The $q$-equivalent of $r!$ is $[1][2]\ldots[r]$, in which $[r]=(q^r-1)/(q-1)$; therefore, in discussing $q$-functions, I think it desirable to use an operative symbol which gives rise to a series in which the coefficients follow the $q$-Binomial form, *i.e.*

$$\Delta^n\Phi(x)=\Phi(q^nx)-[n]\Phi(q^{n-1}x)+q\frac{[n][n-1]}{[2]!}\phi(q^{n-2}x)-\ldots\ldots(-1)q^{\frac{1}{2}n(n-1)}\phi(x)$$

* *Trans. Roy. Soc. Edin.*, vol. xli. pp. 105–118, 399–407, etc. *Proc. L.M.S.*, series 2, vol. ii. pp. 192–221; vol. iii. pp. 1–23.

† Heine, *Kugelfunctionen*, ed. 1878, pp. 99 *et seq*; also Thomæ, *Crelle's Journal*, vol. lxx.

We proceed as follows by defining an operation $\Delta\phi(x)$ as the quotient of two differences.

## § 1. Forms of $\Delta^n$.

$$\Delta\{\Phi(x)\} = \frac{\Phi(qx) - \Phi(x)}{qx - x}, \quad . \quad . \quad . \quad . \quad . \quad (1)$$

We see that in the limiting case, $q = 1$, this equation is $D\{\Phi(x)\} = \Phi'(x)$, provided that $\Phi(x)$ has a first derivative $\Phi'(x)$. Repeating the operation symbolised by $\Delta$, we obtain

$$\Delta^2\{\Phi(x)\} = \frac{\Phi(q^2x) - \frac{(q^2-1)}{(q-1)}\Phi(qx) + q\Phi(x)}{(q^2x - qx)(qx - x)}, \quad . \quad . \quad . \quad . \quad (2)$$

and, by induction it is easy to establish

$$\Delta^n\{\Phi(x)\} = \frac{\Phi(q^nx) - [n]\Phi(q^{n-1}x) + \ldots . (-1)^r q^{r(r-1)/2} \frac{[n]!}{[r]![n-r]!}\Phi(q^{n-r}x) + \ldots . (-1)^n q^{n(n-1)/2}\Phi(x)}{(q^nx - q^{n-1}x)(q^{n-1}x - q^{n-2}x) \ldots . (q^2x - qx)(qx - x)}, \quad (3)$$

in which, as in previous papers, * $[n]$ denotes $(q^n - 1)/(q - 1)$.

In this expression the coefficients of the functions $\phi(q^{n-r}x)$ follow what may be termed the $q$-Binomial form, that is, they are identical with the coefficients in the equation

$$(x+y)(x+qy) \ldots . (x+q^{n-1}y) = x^n + [n]x^{n-1}y + \ldots . + \frac{[n]!}{[r]!\,[n-r]!}q^{\frac{1}{2}r(r-1)}x^{n-r}y^r + \ldots . , \quad (4)$$

By means of the operator $\Delta$, the connection between the $\Delta$-equations satisfied by certain $q$-series functions of $x$ and the linear differential equations satisfied by the simple $(q = 1)$ forms of such series is made clear, for from the equation

$$\Delta\{\Phi(x)\} = \frac{\Phi(qx) - \Phi(x)}{qx - x}, \quad \text{we see} \quad x.\Delta = \frac{q^{x\frac{d}{dx}} - 1}{q - 1},$$

also that with certain restrictions on the nature of $\phi(x)$ we may write

$$\Delta\,.\,u = \frac{du}{dx} + (q-1)\frac{x}{2!}\frac{d^2u}{dx^2} + (q-1)^2\frac{x^2}{3!}\frac{d^3u}{dx^3} + \ldots . , \quad . \quad . \quad . \quad (5)$$

and that $x\Delta$ is related to the differential operator $x\dfrac{d}{dx}$ in a manner analogous to the relation between $n$ and its $q$-form $(q^n - 1)/(q - 1)$.

## § 2. Basic Exponential and Transformation of an Arbitrary Power Series.

The following simple example will suffice at this stage for illustration of the connection between the $q$-operator $\Delta$ and the differential operator $\dfrac{d}{dx}$.

Compare two equations

$$\Delta_x(y) = y, \quad (\alpha)$$
$$\frac{dy}{dx} = y. \quad (\beta)$$

* *Trans. Roy. Soc. Edin.*, vol. xli. pp. 1–28, 105–118, 399–408.

On substituting $\sum c_r x^{a+r}$ in the first equation $(a)$, we find, since $(\Delta x^m = [m]x^{m-1})$, an indicial equation $[a]=0$, and a function

$$x^a + \frac{x^{a+1}}{[a+1]} + \frac{x^{a+2}}{[a+1][a+2]} + \ldots\ldots$$

The equation $[a]=0$, viz. $(q^a-1)/(q-1)=0$, has the doubly infinite system of roots

$$a = \frac{2r\pi i}{\log q + 2s\pi i}, \quad (r=0,\ 1,\ 2,\ 3,\ \ldots.), \quad (s=0,\ 1,\ 2\ \ldots.).$$

From the first or principal root, which is zero, we deduce a solution

$$\begin{aligned} y &= 1 + \frac{x}{[1]} + \frac{x^2}{[2]!} + \frac{x^3}{[3]!} + \ldots\ldots \\ &= \mathrm{E}_q(x). \end{aligned}$$

In connection with this function, which may also be expressed as an infinite product, we note that BOOLE's transformation of an arbitrary power series, viz.

$$a_0 + a_1 x + \frac{a_2 x^2}{2!} + \frac{a_3 x^3}{3!}$$

$$= e^x \left\{ a_0 + x\,.\,\Delta a_0 + \frac{x^2}{2!}\,.\,\Delta^2 a_0 + \frac{x^3}{3!}\,.\,\Delta^3 a_0 + \ldots\ldots \right\}$$

possesses a remarkably simple generalisation, in which $\mathrm{E}_q(x)$ replaces $e_x$, $[2]!$, $[3]!$, .... replace $2!$, $3!$, .... and $q$-operators replace the $\Delta$ operator of BOOLE's formula; thus

$$\Delta^r a_n = (\mathrm{D}-1)(\mathrm{D}-q)\ \ldots\ (\mathrm{D}-q^{r-1})a_n$$

replaces the

$$\Delta^r a_n = (\mathrm{D}-1)^r a_n, \quad \mathrm{D}a_n = a_{n+1},$$

usual in Finite Differences.

I think that these examples will suffice to show that for $q$-functions the natural analogue of the theory of differential equations is the theory of the difference quotient

$$\Delta\Phi(x) = \frac{\Phi(qx)-\Phi(x)}{qx-x} \quad \text{or operator} \quad x\Delta = \frac{q^{x\frac{d}{dx}}-1}{q-1} = [x\mathrm{D}]. \qquad (6)$$

In the later portions of the paper several $\Delta$-equations will be solved, which will show clearly that the theory of $\Delta$-equations is exactly parallel to that of differential equations. Such solutions as HANKEL's solution of BESSEL's equation have a place in the $\Delta$-analogue of BESSEL's equation.

In previous papers the writer made use of an operator

$$\mathrm{D}^{(n)} \equiv \frac{d}{d(x^{q^{n-1}})}\left\{ \frac{d}{d(x^{q^{n-2}})}\left\{ \ldots\ldots \left\{ \frac{d}{d(x^{q^{n-r}})}\left\{ \ldots\ldots \left\{ \frac{d}{d(x^q)}\left\{ \ldots\ldots \left\{ \frac{d}{d(x)} \right\} \ldots \right\} \right.\right.\right.\right.\right.\right.\right.,$$

which could, however, only be applied to such special series as $\sum c x^{[r]}$, and was quite inapplicable to arbitrary functional forms. A comparison of the following equations will show the advantage which the operator $\Delta$ has over $\mathrm{D}^{(n)}$.

$$qx^{[2]}\mathrm{D}^{(2)}y - \mathrm{D}^{(2)}y + \{1-[n]-[-n-1]\}x\mathrm{D}y + [n][-n-1]y = \mathrm{P}'_{[n-2]}(x) - \mathrm{P}'_{[n-2]}(x^q) \qquad (7)$$

has a solution

$$y = x^{[n]} - \frac{[n][n-1]}{[2][2n-1]} q^2 x^{[n-2]} + \ldots\ldots = \mathrm{P}_{[n]}(x)$$

analogous to LEGENDRE's series $\mathrm{P}_n(x)$.

In the case of the $\Delta$ operator we have

$$qx^2\Delta^2 y - \Delta^2 y + \{1 - [n] - [-n-1]\} x\Delta y + [n][-n-1]y = 0, \quad . \quad . \quad . \quad (8)$$

with a solution

$$y = x^n - \frac{[n][n-1]q^2}{[2][2n-1]} x^{n-2} + \ldots\ldots$$

Of course, when we put $q = 1$, the right side of (7) vanishes, and both equations (7) and (8) become identical with LEGENDRE's equation. The $\Delta$-equation is, however, an exact parallel of LEGENDRE's differential equation, and any transformation of LEGENDRE's equation can be at once followed by similar transformations of (8). The presence of the two functions on the right side of (7) prevents our doing this in the case of (7). Moreover, the $\Delta$ operation can be applied at once to product-functions, etc., which is quite impossible in the case of the operations denoted $\mathrm{D}^{(n)}$.

## § 3. ELEMENTARY PROPERTIES OF THE OPERATOR $\Delta$.

So long as we confine ourselves to the direct operations denoted by $\Delta^n$ ($n$ a positive integer), it is clear that $\Delta$ as an operative symbol obeys the laws

$$\Delta^m\{\Delta^n\Phi(x)\} = \Delta^{m+n}\{\Phi(x)\} = \Delta^n\{\Delta^m\Phi(x)\}$$
$$\Delta(u+v) = \Delta u + \Delta v$$
$$\Delta au = a\Delta u.$$

Also in analogy with

$$\frac{d}{dx}(uv) = u\frac{dv}{dx} + v\frac{du}{dx} \quad \text{and} \quad \frac{d}{dx}\left(\frac{u}{v}\right) = \left\{ v\frac{du}{dx} + u\frac{dv}{dx} \right\} \div v^2$$

we have

$$\Delta u_x v_x = v_{qx}\Delta u_x + u_x \Delta v_x$$
$$\Delta\frac{u_x}{v_x} = \frac{v_x\Delta u_x - u_x\Delta v_x}{v_{qx}v_x}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

We note the following special cases :—

| | |
|---|---|
| $\Delta.x^n = [n]x^{n-1}$, | with analogies $\mathrm{D}x^n = nx^{n-1}$. |
| $\Delta^n \mathrm{E}_q(ax) = a^n \mathrm{E}_q(ax)$, | $\mathrm{D}^n \operatorname{Exp.}(ax) = a^n \operatorname{Exp.}(ax)$. |
| $\Delta \log x = \frac{\log q}{q-1} \cdot \frac{1}{x}$, | $\mathrm{D}\log x = \frac{1}{x}$. |
| $\Delta(x-1)(x-q)\ldots(x-q^{n-1}) = [n](x-1)(x-q)\ldots(x-q^{n-2})$, | $\mathrm{D}(x-1)^n = n(x-1)^{n-1}$. |
| $\Delta \mathrm{E}_q(ax).x^n = q^n x^n a\mathrm{E}_q(ax) + [n]x^{n-1}\mathrm{E}_q(ax)$, | $\mathrm{D}e^{ax}x^n = ax^n e^{ax} + nx^{n-1}e^{ax}$. |

From which formulæ corresponding to those of integration by parts may be found and $q$-analogies of $\int_0^\infty e^{-n}x^n dx = \Gamma(n)$ formed, which I leave to a supplementary paper.

## § 4. Interpretation of $\Delta^{-n}$.

If in any function of $x$ we substitute $qx$ for $x$, let the operation be denoted by a prefixed symbol Q, thus $\mathrm{Q} = q^{x\frac{d}{dx}}$ in terms of the differential operator $x\dfrac{d}{dx}$.

$$\mathrm{Q}.f(x) = f(qx),$$

$$\mathrm{Q}^n.f(x) = f(q^n x),$$

so that

$$\mathrm{Q}^{-n}f(x) = f\left(\frac{x}{q^n}\right).$$

Consider now the equation

$$\Delta^n\Phi(x) = \frac{\Phi(q^n x) - [n]\Phi(q^{n-1}x) + \ldots + (-1)^r q^{\frac{1}{2}r(r-1)}\dfrac{[n]!}{[r]!\,[n-r]!}\Phi(q^{n-r}x) + \ldots (-1)^n q^{\frac{1}{2}n(n-1)}\Phi(x)}{(q^n x - q^{n-1}x)\ \ldots\ (q^2x - qx)(qx - x)}. \quad (10)$$

In terms of the operating symbol Q, this may be written

$$\Delta^n\Phi(x) = \frac{\left\{\mathrm{Q}^n - [n]\mathrm{Q}^{n-1} + q\dfrac{[n][n-1]}{[2]!}\mathrm{Q}^{n-2} - \ldots\ldots (-1)^n q^{\frac{1}{2}n(n-1)}\right\}\Phi(x)}{(q^{\frac{1}{2}n(n-1)}(q-1)^n x^n}. \quad (11)$$

The operating function

$$\left\{\mathrm{Q}^n - [n]\mathrm{Q}^{n-1} + \ldots\ldots (-1)^r q^{r(r-1)/2}\frac{[n]!}{[n-r]!\,[r]!}\mathrm{Q}^{n-r} + \ldots\ldots (-1)^n q^{n(n-1)/2}\mathrm{Q}^0\right\},$$

may be expressed by the $q$-Binomial theorem in the form

$$(\mathrm{Q}-1)(\mathrm{Q}-q)(\mathrm{Q}-q^2)\ \ldots\ldots\ (\mathrm{Q}-q^{n-1}),$$

since Q is an operative symbol obeying the laws

$$\mathrm{Q}^m.\mathrm{Q}^n.u = \mathrm{Q}^{m+n}.u = \mathrm{Q}^n.\mathrm{Q}^m u,$$
$$\mathrm{Q}(u+v) = \mathrm{Q}.u + \mathrm{Q}.v,$$
$$\mathrm{Q}.au = a\mathrm{Q}.u,$$

therefore we write

$$\Delta^n u = \frac{(\mathrm{Q}-1)(\mathrm{Q}-q)(\mathrm{Q}-q^2)\ \ldots\ldots\ (\mathrm{Q}-q^{n-1})u}{q^{n(n-1)/2}(q-1)^n x^n}. \quad (12)$$

Now in the case of the "$q$" Binomial series,

$$(1-x)(1-qx)(1-q^2x)\ldots(1-q^{n-1}x) = 1 - [n]x + q\frac{[n][n-1]}{[2]!}x^2 - q^3\frac{[n][n-1][n-2]}{[3]!}x^3 + \ldots\ldots (-1)^n q^{n(n-1)/2}x^n,$$

if we denote the product by $(1-x)_n$, it is found that the equation

$$(1-x)_n = 1 - [n]x + q\frac{[n][n-1]}{[2]!}x^2 - \ldots\ldots$$

is valid for negative and non-integral values of $n$, provided $(1-x)_n$ be suitably interpreted from the following index relations,

$$(1-x)_n(1-q^n x)_m = (1-x)_{n+m} = (1-x)_m(1-q^m x)_n,$$

whence

$$(1-x)_0 = 1,$$

$$(1-x)_{-n} = \frac{1}{(1-q^{-n}x)_n} = \frac{1}{1-q^{-n}x)(1-q^{-n+1}x)\ \ldots\ (1-q^{-2}x)(1-q^{-1}x)},$$

$$= 1 - [-n]x + q\frac{[-n][-n-1]}{[2]!}x^2 - \ldots\ldots \text{ ad inf.}, \quad (12\text{A})$$

which result may be applied in the case of the operative function (12) as follows.

## § 5. Reverse Operation $\Delta^{-1}$ with $q$-Finite Integration.

The operative function

$$(Q-1)(Q-q)(Q-q^2)\ .\ .\ .\ .\ .\ (Q-q^{n-1})$$

may be annulled by

$$\frac{Q^{-n}}{(1-Q^{-1})(1-qQ^{-1})(1-q^2Q^{-1})\ .\ .\ .\ .\ (1-q^{n-1}Q^{-1})},$$

which can be expressed in many different forms, one of which is

$$Q^{-n}\left\{1+\frac{(q^n-1)}{(q-1)}Q^{-1}+\frac{(q^n-1)(q^{n+1}-1)}{(q-1)(q^2-1)}Q^{-2}+\ .\ .\ .\ .\ .\right\},$$

$$=Q^{-n}+[n]Q^{-n-1}+[n][n+1]\frac{Q^{-n-2}}{[2]!}+[n][n+1][n+2]\frac{Q^{-n-3}}{[3]!}+\ .\ .\ .\ .\ .,\qquad .\qquad .\qquad (13)$$

so that the reverse operations indicated by the following equations will be legitimate, provided that the series obtained are finite or convergent.

## § 6. Solution of $\Delta^n u=\phi(x)$.

$$\Delta^n u=\Phi(x),$$

$$u=\Delta^{-n}\Phi(x),$$

$$u=\{Q^{-n}+[n]Q^{-n-1}+\ .\ .\ .\ .\ .\}\{q^{\frac{1}{2}n(n-1)}(q-1)^n x^n\Phi(x)\},$$

$$=q^{\frac{1}{2}n(n-1)}(q-1)^n\left\{Q^{-n}+[n]Q^{-n-1}+\frac{[n][n+1]}{[2]!}Q^{-n-2}+\ .\ .\ .\right\}.x^n\Phi(x).\qquad .\qquad .\qquad (14)$$

Now, since $\Delta x^m=[m]x^{m-1}$, it is plain, that just as in indefinite integration, so here we may introduce an arbitrary periodical * constant of multiplicative periodicity at each performance of the operation $\Delta^{-1}$. An example of such a function, which may be termed a function of multiplicative period $q$, is,

$$f(x)=\sum\left\{a_r\cos\left(\frac{2\pi\log x}{\log q}\right)+b_r\sin\left(\frac{2\pi\log x}{\log q}\right)\right\}$$

satisfying $\qquad \phi(x)=\phi(qx)=\phi(q^n x).$

We obtain then

$$u=a_0+a_1x+\ .\ .\ .\ .\ +a_{n-1}x^{n-1}+q^{\frac{1}{2}n(n-1)}(q-1)^n\left\{\frac{x^n}{q^{n^2}}\Phi\left(\frac{x}{q^n}\right)+[n]\frac{x^n}{q^{n^2+n}}\Phi\left(\frac{x}{q^{n+1}}\right)+\ .\ .\ .\ .\ .\right\}.\qquad (15)$$

The connection of these forms with integration is manifest, for on writing $1+\epsilon$ for $q$, and putting $n=1$, we obtain form (15),

$$u=a_0+a_1x+\ .\ .\ .\ +a_{n-1}x^{n-1}+\epsilon\left\{\frac{x}{(1+\epsilon)}\phi\left(\frac{x}{1+\epsilon}\right)+\frac{x}{(1+\epsilon)^2}\phi\left(\frac{x}{(1+\epsilon)^2}\right)+\ .\ .\ .\ .\ .\right\}$$

and so retaining only terms involving $\epsilon$ and neglecting $\epsilon^2$, $\epsilon^3$, . . . . .

$$u=a_0+a_1x+\ .\ .\ .\ .\ +a_{n-1}x^{n-1}+\mathrm{L}\sum[\epsilon x\phi(x-\epsilon x)+\epsilon x\phi(x-2\epsilon x)+\ .\ .\ .\ .\ .\ ].$$

It is easy to verify (15) in particular cases, for consider

$$u=\frac{1}{(1-x)}\ .\ .\ .\ .\ .\ (\alpha)\quad \text{then}\quad \Delta u=\frac{1}{(1=x)(1-qx)}\ .\ .\ .\ .\ .\ (\beta)$$

* *Cf.* Boole, *Finite Differences*, pp. 46, 47.

If we now reverse the operator $\Delta$ in equation ($\beta$), we obtain

$$u=\Delta^{-1}\left\{\frac{1}{(1-x)(1-qx)}\right\}$$

and (15) becomes

$$u=c+(q-1)\left\{\frac{x}{q\left(1-\frac{x}{q}\right)\left(1-x\right)}+\frac{x}{q^2\left(1-\frac{x}{q^2}\right)\left(1-\frac{x}{q}\right)}+\frac{x}{q^3\left(-1\frac{x}{q^3}\right)\left(1-\frac{x}{q^2}\right)}+\ldots\ldots\right\}$$

On choosing the arbitrary constant $c=1$, and replacing the terms on the left by series of powers of $x$, we find the coefficient of $x^r$ is $[r]\frac{1}{q^r}\left\{1+\frac{1}{q^r}+\frac{1}{q^{rr}}+\ldots\right\}(q-1)$, which $(q>1)$ is identically unity; so that a special value of the series is $1+x+x^2+\ldots\ldots$, or $\frac{1}{(1-x)}$, and the validity of the transformation is justified in this simple case. The result may be expressed also as

$$\frac{x}{(1-x)}=(q-1)\left\{\frac{1}{(1-x)(1-qx)}+\frac{1}{(q-x)(q^2-x)}+\frac{1}{(q^2-x)(q^3-x)}+\ldots\ldots\right\}$$

$|q|>1$.

It will be noticed that such an equation as $\Delta u=\frac{\lambda}{x}$ cannot be solved in this form, though a solution is furnished by

$$u=c+\frac{\lambda(q-1)}{\log q}\log x,$$

reducing, when $q=1$, to $c+\lambda\log x$.

In the same manner, if we perform the operations denoted by $\Delta^n$ on the function

$$\frac{1}{(1-x)(1-qx)(1-q^2x)\ldots\ldots(1-q^{n-1}x)}=u,$$

we obtain

$$\Delta^n u=\frac{[m][m+1]\ldots\ldots[m+n-1]}{(1-x)(1-qx)\ldots\ldots(1-q^{m+n-2}x)(1-q^{m+n-1}x)}.$$

If we solve this by the inverse method, we find in general

$$u=a_0+a_1x+a_2x^2+\ldots\ldots+a_{n-1}x^{n-1}+(q-1)^n q^{\frac{1}{2}n(n-1)}x^n$$

$$\sum\frac{[n][n+1]\ldots[n+r-1]\cdot[m][m+1]\ldots[m+n-1]}{[r]!\,q^{n^2+rn}\left(1-\frac{x}{q^{n+r}}\right)\left(1-\frac{x}{q^{n+r-1}}\right)\ldots\left(1-\frac{x}{q^{r-m+1}}\right)}, \quad (16)$$

one value of which is the particular expression for $u$ given above. This value will be obtained by the following choice of arbitrary constants:

$$a_0=1,$$
$$\ldots\ldots$$
$$\ldots\ldots$$
$$a_r=\frac{[m][m+1]\ldots\ldots[m+r-2][m+r-1]}{[r]!}.$$

We notice that since
$$\Delta \log x = \frac{\log q}{(q-1)} \cdot \frac{1}{x},$$
and
$$\Delta^n \mathrm{E}_q(ax) = a^n \mathrm{E}_q(ax),$$
the equation
$$\Delta^m y + a_1 \Delta^{m-1} y + \ldots\ldots + a_{m-1}\Delta y + a_m y = \phi(x)$$
may be solved by methods similar to those adopted in the case of differential equations of like form. It is obvious that by giving solutions of such equations as
$$\Phi(\Delta)u = \Psi(x),$$
in which $\Phi$ is so chosen that $\Phi^{-1}(\Delta)$ is capable of representation in such series as $\sum \lambda . \Delta^n$, a great variety of $q$ series and relations may be formed: for example, from such equations as
$$(1-q\Delta)(1-q^2\Delta) \ldots\ldots (1-q^m\Delta)u = f(x),$$
so that
$$u = \sum_{n=0}^{\infty} \frac{[m+n-1]!}{[m-1]!\,[n]!}\, q^n \Delta^n f(x).$$

## § 7. Forms of $\Delta^n\Phi(x)$.

In this section of the paper the following forms will be obtained:—
$$\Delta^n\Phi(x) = \sum_{r=0}^{r=\infty} q^{\frac{1}{2}n(n-1)} \frac{[n+r][n+r-1] \ldots\ldots [r+3][r+2][r+1]}{n+r!} x^r \Phi^{(n+r)}(0), \quad \ldots \quad (16a)$$
$$= \sum q^{\frac{1}{2}n(n-1)} \frac{[n+r]!}{n+r!} \cdot \frac{x^r}{[r]!} \Phi^{(n+r)}(0),$$
$$\Delta^n\Phi(x) = \left\{ \mathrm{A}_0 \left(\frac{d}{dx}\right)^n + \mathrm{A}_1 x \left(\frac{d}{dx}\right)^{n+1} + \ldots\ldots + \mathrm{A}_r x^r \left(\frac{d}{dx}\right)^{n+r} + \ldots\ldots \right\} \phi(x),$$
$$\mathrm{A}_r = \left\{ [n]^{n+r} - [n][n-1]^{n+r} + \ldots\ldots (-1)^s q^{\frac{1}{2}s(s-1)} \frac{[n]!}{[n-s]!\,[s]!} [n-s]^{n+r} \right.$$
$$\left. + \ldots\ldots (-1)^n q^{\frac{1}{2}(n+1)(n-2)} [n] \right\} \frac{(q-1)^r}{n+r!\, q^{\frac{1}{2}n(n-1)}},$$
subject to the conditions that $\Phi(x)$ and all its derivatives are finite and continuous.

Theorem (16$a$) can be derived directly from the equation
$$\Delta^n\{\Phi(x)\} = \frac{\Phi(q^n x) - [n]\Phi(q^{n-1}x) + \ldots\ldots (-1)^n q^{\frac{1}{2}n(n-1)}\Phi(x)}{(q^n x - q^{n-1}x)(q^{n-1}x - q^{n-2}x) \ldots\ldots (qx - x)}, \quad \ldots \quad (17)$$
for, on replacing $\Phi(q^n x)$, $\Phi(q^{n-1}x)$, . . . . . by Maclaurin series, we obtain from the numerator an expression
$$\left[\Phi(0) + q^n x\Phi'(0) + \ldots\ldots + \frac{q^{rn}}{r!} x^r \Phi^{(r)}(0) + \ldots\ldots\right]$$
$$-[n]\left[\Phi(0) + q^{n-1}x\Phi'(0) + \ldots\ldots + \frac{q^{r(n-1)}}{r!} x^r \Phi^{(r)}(0) + \ldots\ldots\right]$$
. . . . . .
. . . . . .
. . . . . .
$$(-1)^s q^{\frac{1}{2}s(s-1)} \frac{[n]!}{[n-s]![s]!} \left[\Phi(0) + q^{n-s}x\Phi'(0) + \ldots\ldots + \frac{q^{r(n-s)}}{r!} x^r \Phi^{(r)}(0) + \ldots\ldots\right]$$
. . . . . .
$$(-1)^n q^{\frac{1}{2}n(n-1)} \left[\Phi(0) + x\Phi'(0) + \ldots\ldots + \frac{x^r}{r!} \Phi^{(r)}(0) - \ldots\ldots\right].$$

Arranging this series according to powers of $x$, we find that the term containing $x^r$ is

$$\frac{x^r\Phi^{(r)}(0)}{r!}\left\{q^{rn}-[n]q^{r(n-1)}+\frac{[n][n-1]}{[2]!}q^{r(n-2)+1}+\ldots\ldots+(-1)^s\frac{[n]!}{[n-s]![s]!}q^{r(n-s)+\frac{1}{2}s(s-1)}\right.$$
$$\left.+\ldots\ldots+(-1)^nq^{\frac{1}{2}n(n-1)}\right\}.$$

This expression is well known as being

$$\frac{x^r\Phi^{(r)}(0)}{r!}(q^r-1)(q^{r-1}-1)(q^{r-2}-1)\ldots\ldots(q^{r-n+1}-1)$$

for all values of $r>n$. In case $r<n$ or $=n$, the expression is identically zero.

Hence, taking account of the denominator of (17), $\Delta^n\phi(x)$ may be written in the form

$$\sum_{r=0}^{r=\infty}x^{r-n}\frac{[r][r-1]\ldots\ldots[r-n+1]}{r!}\Phi^{(r)}(0),$$

or, since $[r][r-1]\ldots\ldots[r-n+1]$ contains a zero factor for all values of $r<n$, finally we write

$$\Delta^n\Phi(x)=\sum_{r=0}^{r=\infty}x^r\frac{[n+r]!}{[r]!}\frac{\Phi^{(n+r)}(0)}{n+r!}. \qquad (18)$$

In the equation

$$\Delta\Phi(x)=\frac{\Phi(qx)-\Phi(x)}{qx-x},$$

let us substitute $1+\epsilon$ for $q$; then, in case $\Phi(x+\epsilon x)$ is capable of expansion in the form of TAYLOR's series,

$$\Delta\Phi(x)=\Phi'(x)+\frac{\epsilon x}{2!}\Phi''(x)+\ldots\ldots+\frac{\epsilon^nx^n}{n+1!}\Phi^{(n+1)}(x)+\ldots\ldots$$

Similarly, from the equation

$$\Delta^2\Phi(x)=\frac{\Phi(q^2x)-(q+1)\Phi(qx)+q\Phi(x)}{(q^2x-qx)(qx-x)}$$

it is easy to obtain

$$\Delta^2\Phi(x)=\frac{(\epsilon+2)}{2!}\Phi''(x)+\frac{\epsilon x}{3!}(\epsilon+2)(\epsilon+3)\Phi'''(x)+\ldots\ldots \qquad (19)$$

$$=\sum_{n=1}^{n=\infty}\frac{\epsilon^{n-1}x^{n-1}}{n+1!}(\epsilon+2)\frac{(\epsilon+2)^n-1}{(\epsilon+2)-1}\Phi^{(n+1)}(x), \qquad (20)$$

or symbolically

$$\Delta^2=\frac{(q+1)}{2}\frac{d^2}{dx^2}+\sum_{n=2}^{\infty}\frac{(q-1)^{n-1}(q+1)\{(q+1)^n-1\}x^{n-1}}{n+1!\,q}\left(\frac{d}{dx}\right)^{n+1} \qquad (21)$$

In the same manner, if we replace $q$ by $1+\epsilon$, in the general equation

$$\Delta^n\phi(x)=\frac{\phi(q^nx)-[n]\phi(q^{n-1}x)+\ldots\ldots+(-1)^nq^{\frac{1}{2}n(n-1)}\phi(x)}{(q^nx-q^{n-1}x)(q^{n-1}x-q^{n-2}x)\ldots(qx-x)},$$

and suppose $\phi(x)$ capable of expansion in the form of TAYLOR's series, we obtain

$$\left.\begin{aligned}
&\Delta^n\phi(x)\\
&=\left[\phi(x)+\ldots\ldots+\frac{\{(1+\epsilon)^n-1\}^r}{r!}x_r\phi^{(r)}(x)+\ldots\ldots\right]\\
&-[n]\left[\phi(x)+\ldots\ldots+\frac{\{(1+\epsilon)^{n-1}-1\}^r}{r!}x^r\phi^{(r)}(x)+\ldots\ldots\right]\\
&+q\frac{[n][n-1]}{[2]!}\left[\phi(x)+\ldots\ldots+\frac{\{(1+\epsilon)^{n-2}-1\}^r}{r!}x^r\phi^{(r)}(x)+\ldots\ldots\right]\\
&\qquad\cdots\cdots\cdots\cdots\\
&\qquad\cdots\cdots\cdots\cdots\\
&\qquad\cdots\cdots\cdots\cdots\\
&\qquad\cdots\cdots\cdots\cdots\\
&\qquad\cdots\cdots\cdots\cdots\\
&+(-1)^nq^{\frac{1}{2}n(n-1)}\phi(x)
\end{aligned}\right\}\div q^{\frac{1}{2}n(n-1)}(q-1)^nx^n. \qquad (21a)$$

Collecting the terms in sets according to the orders of $\phi'$, $\phi''$, . . . . . , we find that all terms below the set containing $\phi^{(n)}(x)$ vanish identically, since

$$[n]^m-[n][n-1]^m+q\frac{[n][n-1]}{2!}[n-2]^m+\ldots\ldots+(-1)^nq^{\frac{1}{2}(n-1)(n-)}[n][1]^m\equiv 0$$

for all values of $m$ (an integer) $<n$. This identity is easily established if we consider that

$$\Delta^2\phi(x)=c\phi''(x)+\text{ terms in }\phi''',\ \phi^{(iv)},\ \ldots\ldots,$$

then replacing $q$ by $1+\epsilon$, and operating with $\Delta$, we find

$$\Delta^3\phi(x)=c\frac{\phi''(x+\epsilon x)-\phi''(x)}{\epsilon x}+\text{similar terms in }\phi''',\ \ldots\ldots$$

$$=c_2\phi'''(x)+\ldots\ldots\text{ similar terms in }\phi^{(iv)},\ \phi^{(v)},\ \ldots\ldots$$

and by induction $\Delta^n\phi(x)$, when expressed in terms of $\phi(x)$ and its derivatives, contains neither $\phi(x)$ nor any of the derivatives below $\phi^{(n)}(x)$, so that the coefficient of $\phi^{(m)}(x)$, viz.

$$q^{-\frac{1}{2}n(n-1)}(q-1)^{-n}\left[(q^n-1)^m-[n](q^{n-1}-1)^m+q\frac{[n][n-1]}{[2]!}(q^{n-2}-1)^m-\ldots\ldots\right.$$
$$\left.-(-1)^nq^{(n-1)(n-2)}(q-1)^m[n]\right]\frac{x^{m-n}}{m!}, \qquad (22)$$

is identically zero for all values of $m<n$ ($m$, $n$ being positive integers).

The coefficient of $\phi^{(n+r)}(x)$ is

$$\left[(q^n-1)^{n+r}-[n](q^{n-1}-1)^{n+r}+q\frac{[n][n-1]}{[2]!}(q^{n-2}-1)^{n+r}-\ldots\ldots\right]\frac{x^{n+r}}{n+r!}. \qquad (23)$$

Hence, taking account of the denominator in expression (21$a$), we find

$$\Delta^n\phi(x)=\left\{A_0\left(\frac{d}{dx}\right)^n+A_1x\left(\frac{d}{dx}\right)^{n+1}+A_2x^2\left(\frac{d}{dx}\right)^{n+2}+\ldots\right\}\phi(x), \qquad (24)$$

in which

$$\mathrm{A}_r = \Big\{ [n]^{n+r} - [n][n-1]^{n+r} + \ldots\ldots + (-1)^s q^{\frac{1}{2}s(s-1)} \frac{[n]!}{n-s]!\,[s]!} [n-s]^{n+r} + \ldots\ldots + (-1)^n q^{\frac{1}{2}(n-1)(n-2)} [n] \Big\} \frac{(q-1)^r}{n+r!\; q^{\frac{1}{2}n(n-1)}}, \qquad (25)$$

provided that the functions, on which the operations are performed, are capable of expansion in MACLAURIN'S form. The coefficient $\mathrm{A}_r$ is the $q$-equivalent of the number $\Delta^n.0^m$ tabulated by DE MORGAN and BOOLE (BOOLE'S *Finite Differences*, pp. 19, 20). The development of such expressions as $\Delta^n\Phi(x)\Psi x$ may be shown to be dependent on

$$\Delta_q^{(n)}(\Psi(x)\Phi(x)) = \{\Delta_{q^n} + \mathrm{Q}\Delta'_q\}\{\Delta_{q^{n-1}} + \mathrm{Q}\Delta'_{q^2}\} \ldots\ldots \{\Delta_q + \mathrm{Q}\Delta'_{q^n}\}\{\Phi(x)\Psi(x)\}$$

in which

$$\Delta_{q^r}\Phi(x) = \Phi(qx) - q^r\Phi(x), \quad \Delta_q^{(n)} = \Delta_{q^n}\Delta_{q^{n+1}} \ldots\ldots \Delta_{q^2}\Delta_q, \ \mathrm{Q} \text{ and } \Delta$$

operate on $\Phi(x)$ only. I leave the consideration of these forms, however, to another paper.

## § 8. FORMS OF MACLAURIN'S SERIES.

In (24), putting

$$\Delta^n\Phi(x) = \left[\mathrm{A}_0\left(\frac{d}{dx}\right)^n + \mathrm{A}_1 x\left(\frac{d}{dx}\right)^{n+1} + \ldots\ldots\right]\Phi(x),$$

we see that

$$\Big\{\Delta^n\Phi(x)\Big\}_{x=0} = \mathrm{A}_0\Phi^{(n)}(0),$$

$$= \Big\{ [n]^n - [n][n-1]^n + \ldots\ldots + (-1)^s q^{\frac{1}{2}s(s-1)} \frac{[n]!}{[s]!\,n-s]!} [n-s]^n + \ldots (-1)^n q^{(n-1)(n-2)} [n] \Big\} \frac{\Phi^{(n)}(0)}{n! q^{\frac{1}{2}n(n-1)}},$$

$$= \frac{[n]!}{n!}\Phi^{(n)}(0),$$

so that MACLAURIN'S series takes the following form in $q$-function theory:

$$\Phi(x) = \sum \frac{x^n}{[n]!}\Big\{\Delta^n\Phi(x)_{x=0}\Big\}, \qquad (26)$$

say

$$\Phi(x) = \Phi(0) + \frac{x}{[1]}\Delta\Phi(0) + \frac{x^2}{[2]!}\Delta^2\Phi(0) + \ldots\ldots$$

and a conjugate form

$$\Phi(x) = \Phi(0) + \frac{x}{[1]}\Phi(\Delta.0)0 + \frac{x^2}{[2]!}\Phi(\Delta.0).0^2 + \ldots\ldots$$

where $\Phi(\Delta.0)0^m$ denotes what $\Phi(\Delta)x^m$ becomes when $x=0$.

The special development of this and the analogue of TAYLOR'S theorem I defer to another paper.

## PART II.

### § 1. CERTAIN INFINITE PRODUCTS.

In this section of the paper I propose to investigate the expansion, in series form, of such products as

$$\left(1+a_1x+a_2x^2+\ \ldots\ +a_nx^n\right)\left(1+a_1\frac{x}{q}+a_2\frac{x^2}{q^2}+\ \ldots\ +a_n\frac{x^n}{q^n}\right)\left(1+a_1\frac{x}{q^2}+\ \ldots\ +a_n\frac{x^n}{q^{2n}}\right)\ldots\ldots,$$

$$\frac{\left(1+ax\right)\left(1+\frac{ax}{q}\right)^2\left(1+\frac{ax}{q^2}\right)^3\ \ldots\ldots}{\left(1+bx\right)\left(1+\frac{bx}{q}\right)^2\left(1+\frac{bx}{q^2}\right)^3\ \ldots\ldots},$$

$$\frac{(1+2qx\cos\theta+q^2x^2)(1+2q^2x\cos\theta+q^4x^2)^2(1+2q^3x\cos\theta+q^6x^2)^3\ \ldots\ldots}{(1+2qy\cos\theta+q^2y^2)(1+2q^2y\cos\theta+q^4y^2)^2(1+2q^3y\cos\theta+q^6y^2)^3\ \ldots\ldots},$$

$$=\lambda_0(x,y)+\lambda_1(x,y)\cos2\theta+\lambda_2(x,y)\cos3\theta+\ \ldots\ldots$$

The coefficients $\lambda_0, \lambda_1, \ldots\ \lambda_n(x,y)$ will be seen to have an intimate connection with the $q$ generalisation of BESSEL's Functions denoted by the symbols $J_{[n]}, \mathfrak{J}_{[n]}, \ldots$ in previous papers.

It is easy to see that the $\Delta$-equation

$$\Delta.u=\{c_0+c_1x+c_2x^2+\ \ldots\ +c_{n-1}x^{n-1}\}u \qquad\qquad (27)$$

is satisfied by the convergent infinite product

$$u=\Pi_q(a_1, a_2, a_3, \ldots\ a_n, x),$$

$$=\left(1+a_1x+a_2x^2+\ \ldots\ +a_nx^n\right)\left(1+\frac{a_1}{q}x+\frac{a^2}{q^2}x^2+\ \ldots\ +\frac{a_n}{q^n}x^n\right)\left(1+\frac{a_1}{q^2}x+\frac{a_2}{q^4}x^2+\ \ldots\ +\frac{a^n}{q^{2n}}\right)\ldots\ldots,$$

in which

$$a_1=\frac{(q-1)}{q}c_0,$$

$$a_2=\frac{(q-1)}{q^2}c_1,$$

$$\ldots\ldots$$

$$a_n=\frac{(q-1)}{q^n}c_{n-1}.$$

The general factor of the function is

$$(1+a_1xq^{-r}+a_2x^2q^{-2r}+\ \ldots\ +a_nx^nq^{-nr}).$$

### § 2. EXPANSION AS AN INFINITE SERIES.

An examination of the infinite product shows us that in case the product can be represented by a series of powers of $x$, such series will be of the form $\sum_{r=0}^{\infty}c_rx^r$,

$$=1+\frac{a_1q}{q-1}x+c_2x^2+c_3x^3+\ \ldots\ldots$$

In the equation

$$\Pi_q(x)=\frac{q}{q-1}\Delta^{-1}\left\{(a_1+a_2qx+a_3q^2x^2+\ .\ .\ .\ +a_nq^{n-1}x^{n-1})\Pi_q(x)\right\} \quad . \quad . \quad (28)$$

replacing $\Pi_q$ by the series $\sum c_rx^r$ we obtain

$$\begin{aligned}\sum c_rx^r=\frac{q}{q-1}\Delta^{-1}\Big[&(a_1c_0+a_1c_1x+a_1c_2x^2+\ .\ .\ .\ .\ +a_1c_mx^m+\ .\ .\ .\ .\ .\ )\\&+(qa_2c_0x+qa_2c_1x^2+\ .\ .\ .\ .\ +qa_2c_mx^{m+1}+\ .\ .\ .\ .\ )\\&+(q^2a_3c_0x^2+q^2a_3c_1x^2+\ .\ .\ .\ .\ +q^2a_3c_mx^{m+1}+\ .\ .\ .\ .\ ),\ .\\&\qquad .\ .\ .\ .\ .\ .\ .\ .\ .\ .\ .\\&\qquad .\ .\ .\ .\ .\ .\ .\ .\ .\ .\ .\\&+(q^{n-1}a_nc_0x^{n-1}+q^{n-1}a_nc_1x^n+\ .\ .\ .\ .\ +q^{n-1}a_nc_mx^{m+n-1})\Big].\end{aligned} \quad . \quad (28a)$$

Now $\Delta^{-1}(ax^m)=\mathrm{C}+a\dfrac{x^{m+1}}{[m+1]}$ (C being an arbitrary constant), therefore performing the operation $\Delta^{-1}$ on the terms of this series (28$a$), we obtain

$$\sum c_rx^r=\mathrm{C}+\frac{q}{q-1}a_1c_0x+\frac{q}{q-1}\left(a_1c_1+qa_2c_0\right)\frac{x^2}{[2]}+\frac{q}{q-1}\left(a_1c_2+qa_2c_1+q^2a_3c_0\right)\frac{x^3}{[3]!}+\ .\ .\ .\ .$$

and we find, by equating the coefficients of powers of $x$, that

$$\begin{aligned}&\mathrm{C}=c_0=1,\\&c_1=\frac{q}{q-1}a_1,\\&c_2=\frac{q}{q^2-1}\left(a_1c_1+qa_2\right),\\&c_r=\frac{q}{q^r-1}\left(a_1c_{r-1}+qa_2c_{r-2}+q^2a_3c_{r-3}+\ .\ .\ .\ .\ .\ +q^{n-1}a_nc_{r-n}\right).\end{aligned} \quad . \quad . \quad (29)$$

Subject to the convergence of the series, we write therefore

$$\begin{aligned}\Pi_q(a_1,\ a_2,\ .\ .\ .\ .\ .\ a_n,\ x)=1&+\frac{qa_1}{(q-1)}x+\frac{q^2x^2}{(q^2-1)(q-1)}\left\{a_1^2+(q-1)a_2\right\}\\&+\frac{q^3x^3}{(q^3-1)(q^2-1)(q-1)}\left\{a_1^3+(q-1)a_1a_2+(q^2-1)a_1a_2+(q-1)(q^2-1)a_3\right\}\\&+\frac{q^4x^4}{(4)(3)(2)(1)}\left\{a_1^4+(q-1)a_1^2a_2+(q^2-1)a_1^2a_2+(q-1)(q^2-1)a_1a_3+(q^3-1)a_1^2a_2\right.\\&\left.+(q-1)(q^3-1)a_2^2+(q^3-1)(q^2-1)a_3a_1+(3)(2)(1)a_4\right\}+\ .\ .\ .\ .\ .\end{aligned} \quad . \quad . \quad (30)$$

The recurrence relation connecting $n+1$ successive coefficients being

$$c_r=\frac{q}{(q^r-1)}\left\{a_1c_{r-1}+qa_2c_{r-2}+q^2a_3c_{r-3}+\ .\ .\ .\ .\ .\ +q^{n-1}a_nc_{r-n}\right\}, \quad . \quad . \quad (31)$$

the series is absolutely convergent for all values of $x$, in case $|q|>1$, for the series is seen to be the product of $n$ absolutely convergent series formed as follows :—

Resolve the polynomial $(1+\alpha_1x+\alpha_2x^2+\ .\ .\ .+\alpha_nx^n)$ into its factors $(1+\rho_1x)$ $(1+\rho_2x)(1+\rho_3x)\ .\ .\ .\ (1+\rho_nx)$.

Then

$$\Pi_q(a_1a_2a_3 \ldots a_nx) = \prod_{m=0}^{\infty}\left(1+\frac{\rho_1x}{q^m}\right)\prod_{m=0}^{\infty}\left(1+\frac{\rho_2x}{q^m}\right) \ldots\ldots \prod_{m=0}^{\infty}\left(1+\frac{\rho_nx}{q^m}\right),$$

$$= \left\{1+\frac{\rho_1qx}{(q-1)}+\frac{\rho_1^2q^2x^2}{(q^2-1)(q-1)}+\ldots\ldots\right\}\left\{1+\frac{\rho_2qx}{(q-1)}+\frac{\rho_2^2q^2x^2}{(q^2-1)(q-1)}+\ldots\ldots\right\}$$

$$\ldots\ldots\left\{1+\frac{\rho_nqx}{(q-1)}+\frac{\rho_n^2q^2x^2}{(q^2-1)(q-1)}+\ldots\ldots\right\},$$

and each of these is absolutely convergent for all values of $x$ in case $|q|>1$, as well as for limited values of $x$ in case $|q|<1$.

## § 3. Product of $n$, Theta-Functions.

In this section I propose to obtain a theorem, which may be stated as

$$\Theta(a_1,x)\Theta(a_2,x)\Theta(a_3,x)\ldots\ldots\Theta(a_n,x) = A_0 + A_1\cos 2x + A_2\cos 4x + \ldots\ldots$$

The functions $\Theta(a_1x)\Theta(a_2,x)\ldots\ldots$ each reduce to Jacobi's function $\Theta$, in case the parameters $a_1$, $a_2$, $a_3$, $\ldots\ldots$ are each equal to unity.

We have above obtained the expansion of the infinite product $\Pi_q(a_1, a_2, a_3, \ldots a_n, x)$, in the form of a power series $\sum c_rx^r$, viz.—

$$\prod_{m=0}^{m=\infty}\left(1+\frac{a_1x}{q^m}+\frac{a_2x^2}{q^{2m}}+\frac{a_3x^3}{q^{3m}}+\ldots+\frac{a_nx^n}{q^{nm}}\right) = 1+\frac{qa_1}{(q-1)}x+\frac{q^2x^2}{(q^2-1)(q-1)}\left\{a_1^2+(q-1)a_2\right\}+\ldots\ldots$$

Change $q$ into $q^{-2}$, and let $(1+\rho_1x)(1+\rho_2x)\ldots(1+\rho_nx) = (1+a_1x+a_2x^2+\ldots+a_nx^n)$. We write then

$$\Pi_{q^{-2}}(a_1a_2a_3\ldots\ldots a_nx) = \prod_{m=0}^{m=\infty}(1+\rho_1q^{2m}x).\prod_{m=0}^{m=\infty}(1+\rho_2q^{2m}x)\ldots\ldots\prod_{m=0}^{m=\infty}(1+\rho_nq^{2m}x),$$

$$\Pi_{q^{-2}}(a_1,a_2,a_3\ldots\ldots a_n,xt).\Pi_{q^{-2}}(a_1,a_2,a_3\ldots\ldots a_n,xt^{-1}) = \prod_{m=0}^{\infty}(1+\rho_1xq^{2m}(t+t^{-1})$$

$$+\rho_1^2x^2q^{4m})\ldots\ldots\prod_{m=0}^{\infty}(1+\rho_nxq^{2m}(t+t^{-1})+\rho_n^2x^2q^{4m}). \quad (32)$$

Now $\rho_1$, $\rho_2$, $\ldots\ldots$ $\rho_n$ are independent constants, for we may choose $n$ arbitrary factors

$$(1+\rho_1x)(1+\rho_2x)\ldots(1+\rho_nx) \quad \text{to form a polynomial} \quad (1+a_1x+a_2x^2+\ldots+a_nx^n).$$

Replacing $\Pi_{q^{-2}}(xt)$ and $\Pi_{q^{-2}}(xt^{-1})$ by their series expressions $\sum c_rx^rt^r$, and $\sum c_rx^rt^{-r}$, we obtain from the product of these series

$$\Pi_{q^{-2}}(a_1a_2a_3\ldots a_n,xt)\Pi_{q^{-2}}(a_1a_2\ldots a_n,xt^{-1}) = J_0+2J_1(t+t^{-1})+2J_2(t^2+t^{-2})+\ldots\ldots \quad (33)$$

$J_0$, $J_1$, $J_2$, $\ldots\ldots$, are infinite series functions of $x$, reducing in special cases to Bessel's functions,

$$J_0 = 1+\frac{a_1^2x^2}{(q^2-1)^2}+\frac{x^4}{(q^4-1)^2(q^2-1)^2}(q^2a_1^2+a_2-q^2a_2)^2+\ldots\ldots \quad (34)$$

The coefficient of $x^{2m}$ is $c_m^{\,2}$, which is determined by the recurrence relation

$$c_m = \frac{q^{2m-2}}{(1-q^{2m})}\left\{ a_1 c_{m-1} + \frac{1}{q^2} a_2 c_{m-2} + \frac{1}{q^4} a_3 c_{m-3} + \ldots + \frac{1}{q^{2n-2}} a_n c_{m-n} \right\}, \quad . \quad . \quad (35)$$

$$\mathrm{J}_m = x^m \{ c_{m+0} c_0 + c_{m+1} c x_1^{\,2} + c_{m+2} c_2 x^4 + \ldots \}, \quad . \quad . \quad . \quad (36)$$

in which the coefficient of $x^{m+2r}$ is $c_{m+2r}.c_{2r}$, in which $c_{m+2r}$ and $c_{2r}$ respectively are determined by the above recurrence relation (35).

## § 4. Expression for $\Theta^n(x)$.

We have now established the form

$$\prod_{m=0}^{\infty}\left\{ 1 + 2q^{2m}x\rho_1 \cos 2\theta + q^{4m}x^2\rho_1^{\,2} \right\} \prod_{m=0}^{\infty}\left\{ 1 + 2q^{2m}x\rho_2 \cos 2\theta + q^{4m}x^2\rho_2^{\,2} \right\} \ldots \ldots$$

$$\prod_{m=0}^{\infty}\left\{ 1 + 2q^{2m}x\rho_n \cos 2\theta + q^{4m}x^2\rho_n^{\,2} \right\}, = \mathrm{J}_0 + 2\mathrm{J}_1 . \cos 2\theta + 2\mathrm{J}_2 . \cos 4\theta + \ldots \ldots \quad . \quad (37)$$

the constants $\rho_1\rho_2 \ldots \rho_n$, being connected with the constants $a_1, a_2, \ldots a_n$, parameters of the J functions, by the relation $(1+\rho_1 x)(1+\rho_2 x) \ldots (1+\rho_n x) = 1 + a_1 x + a_2 x^2 + \ldots + a_n x^n$.

Thus, if we choose $\rho_1 = \rho_2 = \ldots = \rho_n = 1$, $a_1 = n$, $a_2 = \dfrac{n(n-1)}{2!}$, $\ldots$ $a_n = 1$, and put $q^{-1}$ for $x$, we shall obtain the $n^{\text{th}}$ power of Jacobi's $\Theta$ function

$$\Theta^n\left(\frac{2\mathrm{K}\theta}{\pi}\right) = \left\{ \prod_{m=1}^{\infty}(1-q^{2m}) \right\}^n \left[ \mathrm{J}_0 + 2\mathrm{J}_1 \cos 2\theta + 2\mathrm{J}_2 \cos 4\theta + \ldots \ldots \right], \quad . \quad . \quad (38)$$

in which

$$\mathrm{J}_0 = 1 + \frac{n^2}{q^2(q^2-1)^2} + \frac{n^2\{n^2q^2 + nq^2 + n^2 - n\}^2}{q^4(q^4-1)^2(q^2-1)^2} + \ldots \ldots + \frac{c_r^{\,2}}{q^{2r}} + \ldots \ldots, \quad . \quad . \quad (39)$$

the other coefficients being determined by means of the recurrence relation

$$c_m = \frac{q^{2m-2}}{(1-q^{2m})}\left\{ n c_{m-1} + \frac{n(n-1)}{2!} q^{-2} c_{m-2} + \frac{n(n-1)(n-2)}{3!} q^{-4} c_{m-3} + \ldots \ldots + q^{2-2n} c_{m-n} \right\}$$

$$\mathrm{J}^m = q^{-m}\{ c_m c_0 + q^{-2} c_{m+1} c_1 + q^{-4} c_{m+2} c_2 + \ldots \ldots \} \quad . \quad . \quad . \quad . \quad . \quad (40)$$

The simplest case of the product $\Pi_q(a_1 a_2 \ldots a_n, x)$ is when $a_1 = a(q-1)/q$, and $a_2 a_3, \ldots \ldots$, are each zero. In this case the above product and series become

$$\left\{ 1 + a\frac{(q-1)}{q}x \right\}\left\{ 1 + a\frac{(q-1)}{q^2}x \right\}\left\{ 1 + a\frac{(q-1)}{q^3}x \right\} \ldots \ldots = 1 + \frac{x}{[1]} + \frac{x^2}{[2]!} + \ldots \ldots$$

which we saw in (9) was a solution of $\Delta y = ay$, and was there denoted $\mathrm{E}_q(ax)$. This product and series is, of course, well known as

$$\left(1+\frac{x}{q}\right)\left(1+\frac{x}{q^2}\right) \ldots \ldots = 1 + \frac{x}{(q-1)} + \frac{x^2}{(q^2-1)(q-1)} + \ldots \ldots$$

If in the series $\mathrm{E}_q(ax)$ we replace $q$ by $q^{-1}$, which we term inverting the base, we find

$$\mathrm{E}_{q^{-1}}(ax) = 1 + \frac{ax}{[1]} + q\frac{a^2x^2}{[2]!} + q^3\frac{a^3x^3}{[3]!} + \ldots \ldots$$

with for limited values of $x$ a common region of convergence with $E_q(ax)$. We shall subsequently require the properties

$$E_q(ax)E_{q^{-1}}(-ax)=1 \quad . \quad . \quad . \quad . \quad . \quad (41)$$

$$E_q(ax)E_{q^{-1}}(bx)=1+\frac{(a+b)}{[1]}x+\frac{(a+b)(a+qb)}{[2]!}x^2+\ldots\ldots$$

## § 5. "Double Product Theta-Functions."

Consider a function $\Phi(x)$, of the form

$$\Phi(x)=\frac{\phi(x).\phi\left(\frac{x}{q}\right).\phi\left(\frac{x}{q^2}\right)\ldots\ldots \text{ ad inf.}}{\psi(x).\psi\left(\frac{x}{q}\right).\psi\left(\frac{x}{q^2}\right)\ldots\ldots \text{ ad inf.}}, \quad . \quad . \quad . \quad . \quad (42)$$

In case the infinite product is convergent, we may write

$$\Delta\Phi(x)=\frac{\phi(xq)-\psi(xq)}{x(q-1)\psi(xq)}\Phi(x), \quad . \quad . \quad . \quad . \quad (43)$$

and by means of (15)

$$\Phi(x)=c+\frac{\phi(x)-\psi(x)}{\psi(x)}\Phi\left(\frac{x}{q}\right)+\frac{\phi\left(\frac{x}{q}\right)-\psi\left(\frac{x}{q}\right)}{\psi\left(\frac{x}{q}\right)}\Phi\left(\frac{x}{q^2}\right)+\ldots\ldots \quad . \quad . \quad . \quad (44)$$

Let us now consider the special function $\Phi(x)$, in which $\phi(x)=E_q(\alpha x)$, $\psi(x)=E_q(bx)$, so that

$$\Phi(qx)=\frac{E_q(aqx)}{E_q(bqx)}\Phi(x), \quad . \quad . \quad . \quad . \quad . \quad (45)$$

From (45) we have at once by means of (41)

$$\Phi(qx)=\left\{1+\frac{(a-b)}{[1]}qx+\frac{(a-b)(a-qb)}{[2]!}q^2x^2+\ldots\ldots+\frac{(a-b)\ldots(a-q^{r-1}b)}{[r]!}q^rx^r+\ldots\right\}\Phi(x), \quad (46)$$

so that, in case $\Phi(x)$ can be expressed as a series of positive powers of $x$, as seems possible (*a priori*) from the nature of the infinite product, which is of the form

$$\frac{\left(1+ax\right)\left(1+\frac{a}{q}x\right)^2\left(1+\frac{a}{q^2}x\right)^3\ldots\ldots}{\left(1+\beta x\right)\left(1+\frac{\beta}{q}x\right)^2\left(1+\frac{\beta}{q^2}x\right)^3\ldots\ldots}, \quad . \quad . \quad . \quad . \quad (47)$$

we shall have the following relations to determine the coefficients in the expansion

$$\Phi(x)=c_0+c_1x+c_2x^2+\ldots\ldots,$$

$$c_0=1,$$

$$c_1+q\frac{a-b}{[1]}=c_1q,$$

$$c_2+\frac{a-b}{[1]}qc_1+\frac{(a-b)(a-qb)}{[2]!}q^2c_0=c_2q^2,$$

$$\ldots\ldots\ldots\ldots\ldots\ldots$$

$$c_n(q^n-1)=\frac{(a-b)}{[1]}qc_{n-1}+\frac{(a-b)(a-qb)}{[2]!}q^2c_{n-2}+\ldots\ldots+\frac{(a-b)(a-qb)\ldots(a-q^{n-1}b)}{[n]!}q^nc_0, \quad (48)$$

which determines the form of the series expansion of the infinite product

$$\frac{\left(1+\frac{ax(q-1)}{q}\right)\left(1+\frac{ax(q-1)}{q^2}\right)^2\left(1+\frac{ax(q-1)}{q^3}\right)^3 \ldots\ldots}{\left(1+\frac{bx(q-1)}{q}\right)\left(1+\frac{bx(q-1)}{q^2}\right)^2\left(1+\frac{bx(q-1)}{q^3}\right)^3 \ldots\ldots} \quad . \quad . \quad . \quad (49)$$

or, as it may be expressed in terms of the function $\mathrm{E}_q(x)$,

$$\frac{\mathrm{E}_q(ax)\mathrm{E}_q\left(\frac{ax}{q}\right)\mathrm{E}_q\left(\frac{ax}{q^2}\right) \ldots\ldots}{\mathrm{E}_q(bx)\mathrm{E}_q\left(\frac{bx}{q}\right)\mathrm{E}_q\left(\frac{bx}{q^2}\right) \ldots\ldots}\text{ad inf.} \quad . \quad . \quad . \quad . \quad (50)$$

## § 6. Double Product Theta-Functions.

Some interesting relations exist between the coefficients $c_0c_1c_2 \ldots\ldots$ and the generalisation of Bessel's Function denoted $\mathrm{J}_{[n]}(x)$ in previous papers (*loc. cit.*).

From the relation

$$\Phi(qx)=\frac{\mathrm{E}_q(aqx)}{\mathrm{E}_q(bqx)}\cdot\Phi(x) \quad . \quad . \quad . \quad . \quad . \quad (51)$$

we form

$$\frac{\left(1+\frac{axt}{q}\right)\left(1+\frac{axt}{q^2}\right)^2\left(1+\frac{axt}{q^3}\right)^3 \ldots\ldots}{\left(1+\frac{bxt}{q}\right)\left(1+\frac{bxt}{q^2}\right)^2\left(1+\frac{bxt}{q^3}\right)^3 \ldots\ldots}=1+c_1xt+c_2x^2t^2+\ldots\ldots,$$

$$\frac{\left(1+\frac{axt^{-1}}{q}\right)\left(1+\frac{axt^{-1}}{q^2}\right)^2\left(1+\frac{axt^{-1}}{q^3}\right)^3 \ldots\ldots}{\left(1+\frac{bxt^{-1}}{q}\right)\left(1+\frac{bxt^{-1}}{q^2}\right)^2\left(1+\frac{bxt^{-1}}{q^3}\right)^3 \ldots\ldots}=1+c_1xt^{-1}+c_2x^2t^{-2}+\ldots\ldots,$$

in which

$$\begin{aligned}
(q-1)c_1&=\frac{(a-b)}{(q-1)}q,\\
c_2(q^2-1)&=\frac{(a-b)}{(q-1)}qc_1+\frac{(a-b)(a-qb)}{((q-1(q^2-1)}q^2c_0,\\
&\ldots\ldots\ldots\ldots\ldots\ldots\\
c_n(q^n-1)&=\frac{(a-b)}{(q-1)}qc_{n-1}+\frac{(a-b)(a-qb)}{(q-1)(q^2-1)}q^2c_{n-2}+\ldots\ldots+\frac{(a-b)(a-qb)\ldots(a-q^{n-1}b)}{(q-1)(q^2-1)\ldots(q^n-1}q^nc_0. \quad (52)
\end{aligned}$$

Whence

$$\frac{(1+2axq^{-1}\cos 2\theta+a^2x^2q^{-2})(1+2axq^{-2}\cos 2\theta+a^2x^2q^{-4})^2(1+2axq^{-3}\cos 2\theta+a^2x^2q^{-6})^3 \ldots\ldots}{(1+2bxq^{-1}\cos 2\theta+b^2x^2q^{-2})(1+2bxq^{-2}\cos 2\theta+b^2x^2q^{-4})^2(1+2bxq^{-3}\cos 2\theta+b^2x^2q^{-6})^3 \ldots\ldots}$$
$$=\sum c_rx^re^{2ri\theta}\cdot\times\sum c_rx^re^{-2ri\theta}=\lambda_0(x)+2\lambda_1(x)\cos 2\theta+2\lambda_2(x)\cos 4\theta+\ldots\ldots \quad (53)$$

or, by changing $q^{-1}$ into $q^2$,

$$\left(\frac{1\cdot+2axq^2\cos 2\theta+a^2x^2q^4}{1+2bxq^2\cos 2\theta+b^2x^2q^4}\right)^1\left(\frac{1+2axq^4\cos 2\theta+a^2x^2q^8}{1+2bxq^4\cos 2\theta+b^2x^2q^8}\right)^2\left(\frac{1+2axq^6\cos 2\theta+a^2x^2q^{12}}{1+2bxq^6\cos 2\theta+b^2x^2q^{12}}\right)^3 \ldots\ldots\text{ad inf.},$$
$$=\mu_0(x)+2\mu_1(x)\cos 2\theta+2\mu_2(x)\cos 4\theta+\ldots\ldots \quad . \quad . \quad . \quad (54)$$

in which

$$\mu_0(x) = c_0^2 + c_1^2x^2 + c_2^2x^4 + \ldots\ldots + c_r^2x^{2r} + \ldots\ldots,$$
$$\mu_n(x) = c_nc_0x^n + c_{n+1}c_1x^{n+2} + \ldots\ldots + c_{n+r}c_rx^{n+2r} + \ldots\ldots,$$

$c_r$ being determined by the relation

$$\frac{(1-q^{2r})}{q_{2r}}c_r = \frac{(a-b)}{(1-q^2)}c_{r-1} + \frac{(a-b)(q^2a-b)}{(1-q^2)(1-q^4)}c_{r-2} + \frac{(a-b)(q^2a-b)(q^4a-b)}{(1-q^2)(1-q^4)(1-q^6)}c_{r-2} + \ldots\ldots$$
$$+ \frac{(a-b)(q^2a-b)\ldots(q^{2r-2}a-b)}{(1-q^2)(1-q^4)\ldots(1-q)^{2r}}c_0.$$

## § 7. Coefficients $\mu_n$, $\nu_n$ related to $\lambda_n$.

Putting $b=0$, we obtain

$$(1+2axq^2\cos 2\theta + a^2x^2q^4)^1(1+2axq^4\cos 2\theta + a^2x^2q^8)^2 \ldots\ldots,$$
$$\nu_0(x) + 2\nu_1(x)\cos 2\theta + 2\nu_2(x)\cos 4\theta + \ldots\ldots, \quad . \quad . \quad . \quad (55)$$

in which

$$\nu_n(x) = c_nc_0x^n + c_{n+1}c_1x^{n+2} + \ldots\ldots,$$
$$c_r\frac{(1-q^{2r})}{q^{2r}} = \frac{ac_{r-1}}{(1-q^2} + q^2\frac{a^2c_{r-2}}{(1-q^2)(1-q^4)} + \ldots\ldots + q^{r(r-1)}\frac{a^rc_0}{(1-q^2)(1-q^4)\ldots\ldots(1-q^{2r})}. \quad . \quad (56)$$

Similarly, we may show that

$$\frac{1}{(1+2axq^2\cos 2\theta + a^2x^2q^4)^1(1+2axq^4\cos 2\theta + a^2x^2q^8)^2(1+2axq^6\cos 2\theta + a^2x^2q^{12})^3\ldots\ldots} \quad . \quad (56a)$$
$$= \lambda_0(x) + 2\lambda_1(x)\cos 2\theta + 2\lambda_2(x)\cos 4\theta + \ldots\ldots,$$

in which

$$\lambda_n(x) = c_nc_0x^n + c_{n-1}c_1x^{n+2} + \ldots\ldots$$
$$\frac{(1-q^{2r})}{q^{2r}}c_r = \frac{^2ac_{r-1}}{(q^2-1)} + \frac{a^2c_{r-2}}{(q^2-1)(q^4-1)} + \ldots\ldots + \frac{a^rc_0}{(q^2-1)(q^4-1)\ldots(q^{2r}-1)}. \quad . \quad (57)$$

It is not difficult to see that

$$\nu_0(x) = \lambda_0(x)\mu_0(x) + 2\lambda_1(x)\mu_1(x) + 2\lambda_2(x)\mu_2(x) + \ldots\ldots,$$
$$\nu_r(x) = \sum_{r=0}^{\infty}(\mu_{r+1}(x)\lambda_r(x) + \mu_r(x)\lambda_{r+1}(x)).$$

We shall now obtain certain relations connecting these coefficients with the $q$ generalisation of Bessel's Function.

## § 8. Connection of Coefficients with $q$-Bessel Coefficients.

To show the connection between the coefficients $\lambda$, $\mu$, $\nu$, and the $q$ generalisations of Bessel's coefficients we proceed as follows :—

$$\Phi_q(x) = \frac{\mathrm{E}_q(ax)\mathrm{E}_q\left(\frac{ax}{q}\right)\mathrm{E}_q\left(\frac{ax}{q^2}\right)\ldots\ldots}{\mathrm{E}_q(bx)\mathrm{E}_q\left(\frac{bx}{q}\right)\mathrm{E}_q\left(\frac{bx}{q^2}\right)\ldots\ldots}, \quad . \quad . \quad . \quad . \quad (58)$$

$$= \frac{\left[1+\frac{ax(q-1)}{q}\right]\left[1+\frac{ax(q-1)}{q^2}\right]^2\left[1+\frac{ax(q-1)}{q^3}\right]^3\ldots\ldots}{\left[1+\frac{bx(q-1)}{q}\right]\left[1+\frac{bx(q-1)}{q^2}\right]^2\left[1+\frac{bx(q-1)}{q^3}\right]^3\ldots\ldots}. \quad . \quad . \quad (59)$$

We see that

$$\Phi_q\left(\frac{x}{q-1}\right)=\frac{(1+axq^{-1})(1+axq^{-2})^2(1+axq^{-3})^3\ \ldots\ldots}{(1+bxq^{-1})(1+bxq^{-2})^2(1+bxq^{-3})^3\ \ldots\ldots}, \qquad (60)$$

and that

$$\Phi_{q^{-2}}\left(\frac{q^2x}{1-q^2}\right)=\frac{(1+axq^2)(1+axq^4)^2(1+axq^6)^3\ \ldots\ldots}{(1-bxq^2)(1+bxq^4)^2(1+bxq^6)^3\ \ldots\ldots},$$

also

$$\Phi_{q^{-2}}\left(\frac{q^2x}{1-q^2}\right)=\frac{\mathrm{E}_{q^{-2}}\left(\frac{aq^2x}{1-q^2}\right)\Phi_{q^{-2}}\left(\frac{qx}{1-q^2}\right)}{\mathrm{E}_{q^{-2}}\left(\frac{bq^2x}{1-q^2}\right)},$$

and

$$\frac{\Phi_{q^{-2}}\left(\frac{q^2xt^2}{1-q^2}\right)\Phi_{q^{-2}}\left(\frac{q^2xt^{-2}}{1-q^2}\right)}{\Phi_{q^{-2}}\left(\frac{qxt^2}{1-q^2}\right)\Phi_{q^{-2}}\left(\frac{qxt^{-2}}{1-q^2}\right)}=\frac{\mathrm{E}_{q^{-2}}\left(\frac{aq^2xt^2}{1-q^2}\right)\mathrm{E}_{q^{-2}}\left(\frac{aq^2xt^{-2}}{1-q^2}\right)}{\mathrm{E}_{q^{-3}}\left(\frac{bq^2xt^2}{1-q^2}\right)\mathrm{E}_{q^{-2}}\left(\frac{bq^2xt^{-2}}{1-q^2}\right)}. \qquad (61)$$

The expression on the left side of this equation is by (47) and (49)

$$\frac{[1+axq^2(t^2+t^2)+a^2x^2q^4]^1[1+axq^4(t^2+t^{-2})+a^2x^2q^8]^2\ \ldots\ldots}{[1+bxq^2(t^2+t^{-2})+b^2x^2q^4]^1[1+bxq^4(t^2+t^{-2})+b^2x^2q^8]^2\ \ldots\ldots}, \qquad (62)$$
$$=\mu_0(x)+\mu_1(x)(t^2+t^{-2})+\mu_2(x)(t^4+t^{-4})+\ \ldots\ldots$$

The expression on the right side of equation (61) may be given in various forms, owing to the following properties of the function $\mathrm{E}_q(x)$,

$$\mathrm{E}_q(x)\times\mathrm{E}_{q^{-1}}(-x)=1, \qquad (63)$$
$$\frac{\mathrm{E}_q(a)}{\mathrm{E}_q(b)}=\mathrm{E}_q(a)\times\mathrm{E}_{q^{-1}}(-b)=1+\frac{(a-b)}{[1]}+\frac{(a-b)(a-qb)}{[2]!}+\ \ldots\ldots$$

We shall first transform the expression on the right side of (61) into

$$\frac{\mathrm{E}_{q^2}\left(\frac{bq^2xt^2}{q^2-1}\right)\mathrm{E}_{q^2}\left(\frac{bq^2xt^{-2}}{q^2-1}\right)}{\mathrm{E}_{q^2}\left(\frac{aq^2xt^2}{q^2-1}\right)\mathrm{E}_{q^2}\left(\frac{aq^2xt^{-2}}{q^2-1}\right)}. \qquad (64)$$

Now I have shown * that

$$\mathrm{E}_{q^2}\left(\frac{\lambda t^2}{[2]}\right)\mathrm{E}_{q^2}\left(\frac{\lambda t^{-2}}{[2]}\right),$$
$$=\mathrm{J}_{[0]}(\lambda)+(t^2+t^{-2})\mathrm{J}_{[1]}(\lambda)+\ \ldots\ldots+(t^{2m}+t^{-2m})\mathrm{J}_{[n]}(\lambda)+\ \ldots\ldots,$$
$$\mathrm{J}_{[n]}(\lambda)=\sum_{r=0}^{r=\infty}\frac{\lambda^{n+2r}}{\{2n+2r\}!\,\{2r\}!}.$$

Replacing in (64) $\frac{bq^2x}{q^2-1}$ by $\frac{ux}{[2]}$, for convenience of writing, and $\frac{aq^2x}{q^2-1}$ by $\frac{vx}{[2]}$, we have finally

$$\frac{\mu_0(x)+\mu_1(x)(t^2+t^{-2})+\ \ldots\ldots}{\mu_0\left(\frac{x}{q}\right)+\mu_1\left(\frac{x}{q}\right)\left(t^2+t^{-2}\right)}=\frac{\mathrm{J}_{[0]}(ux)+(t^2+t^{-2})\mathrm{J}_{[1]}(ux)+\ \ldots\ldots}{\mathrm{J}_{[0]}(vx)+(t^2+t^{-2})\mathrm{J}_{[1]}(vx)+\ \ldots\ldots}. \qquad (65)$$

* *Proc. L.M.S.*, series 2, vol. ii. p. 196.

Now

$$\mathrm{E}_{q^2}\left(\frac{ux}{[2]}\right) \div \mathrm{E}_{q^2}\left(\frac{vx}{[2]}\right)$$
$$= 1 + \frac{(u-v)x}{[2]} + \frac{(u-v)(u-q^2v)x^2}{[2][4]} + \frac{(u-v)(u-q^2v)(u-q^4v)x^3}{[2][4][6]} + \ldots\ldots, \quad . \quad . \quad (66)$$

so that the expression (64) may be written

$$\left[1 + \frac{(u-v)xt^2}{[2]} + \frac{(u-v)(u-q^2v)}{[2][4]}x^2t^4 + \ldots\ldots\right] \times \left[1 + \frac{(u-v)xt^{-2}}{[2]} + \frac{(u-v)(u-q^2v)}{[2][4]}x^2t^{-4} + \ldots\ldots\right], \quad (67)$$
$$= \mathfrak{J}_0 + (t^2+t^{-2})\mathfrak{J}_1 + (t^4+t^{-4})\mathfrak{J}_2 + \ldots\ldots,$$

in which the coefficients $\mathfrak{J}$ are $q$ analogues of BESSEL's function $\mathrm{J}_n(u-v)$. We see that

$$\mathfrak{J}_n = \frac{(u-v)(u-q^2v)\ldots(u-q^{2n-2}v)}{[2][4]\ldots[2n]}\left\{1 + \frac{(u-v)(u-q^{2n}v)}{[2n+2][2]} + \frac{(u-v)(u-q^2v)(u-q^{2n}v)(u-q^{2n+2}v)}{[2n+2][2n+4][2][4]} + \ldots\ldots\right\}, \quad (68)$$
$$= \mathfrak{J}_n(u, -v).$$

The $q$, or quasi-addition theorem, for this function is, in the notation of a former paper,

$$\mathfrak{J}_0(u, +v) = \mathrm{J}_{[0]}(u)\mathfrak{J}_{[0]}(v) + \frac{[4]}{[2]}\mathrm{J}_{[1]}(u)\mathfrak{J}_{[1]}(v) + \frac{[8]}{[4]}\mathrm{J}_{[2]}(u)\mathfrak{J}_{[2]}(v) + \ldots\ldots$$

$$\mathfrak{J}_n(u, +v) = \sum_{m=-\infty}^{+\infty} \mathrm{J}_{[m]}(u)\mathfrak{J}_{[n-m]}(v)q^{(n-m)(n-m-1)},$$

in which

$$\mathrm{J}_{[m]}(u) = \sum \frac{u^{n+2r}}{\{2n+2r\}!\,\{2r\}!} = \sum \frac{u^{n+2r}}{\Gamma_q(n+r+1)\Gamma_q(r+1)(2)_{n+r}(2)_r},$$
$$\mathfrak{J}_{[m]}(v) = \sum \frac{v^{m+2r}}{\{2m+2r\}!\,\{2r\}!}q^{2r(m+r)}.$$

$\mathfrak{J}_{[n]}$ is not a function distinct from $\mathrm{J}_{[n]}$, but can be derived from $\mathrm{J}_{[n]}$ by inversion of the base $q$. It will be more convenient in subsequent work to denote these functions $\mathrm{J}_q(n, x)$ and $\mathrm{J}_{q^{-1}}(n, x)$ respectively, which will show explicitly that they are $q$-functions, and in what manner they are related to one another. For a detailed discussion of their properties I refer to *Proc. L.M.S.*, series 2, vol. ii. pp. 193–220, vol. iii. pp. 1–24; *Trans. R.S.E.*, vol. xli. pp. 401–408, pp. 105–118; *Proc. R.S.*, vol. lxxvi. A., pp. 127–145, vol. lxxiv. pp. 64–72.

From (61), (64), and (67) we obtain

$$\frac{\mu_0(x) + (t^2+t^{-2})\mu_1(x) + (t^4+t^{-4})\mu_2(x) + \ldots\ldots}{\mu_0\left(\frac{x}{q}\right) + (t^2+t^{-2})\mu_1\left(\frac{x}{q}\right) + (t^4+t^{-4})\mu_2\left(\frac{x}{q}\right) + \ldots\ldots}$$
$$= \mathfrak{J}_0(u, v) + (t^2+t^{-2})\mathfrak{J}_1(u, v) + \ldots\ldots, \quad . \quad (69)$$

whence we derive

$$\mu_0(x) = \mu_0\left(\frac{x}{q}\right)\mathfrak{J}_0 + 2\mu_1\left(\frac{x}{q}\right)\mathfrak{J}_1 + 2\mu_2\left(\frac{x}{q}\right)\mathfrak{J}_2 + \ldots\ldots,$$

$$\mu_n(x) = \sum_{r=0}^{\infty}\left\{\mu_r\left(\frac{x}{q}\right)\mathfrak{J}_{n+r} + \mu_{n+r}\left(\frac{x}{q}\right)\mathfrak{J}_r\right\}. \quad . \quad . \quad . \quad . \quad (70)$$

Similarly, from (55)–(56A) we obtain

$$\nu_0\left(\frac{x}{q}\right)=\nu_0(x)\mathrm{J}_{[0]}(vx)+2\nu_1(x)\mathrm{J}_{[1]}(vx)+2\nu_2(x)\mathrm{J}_{[2]}(vx)+\ .\ .\ .\ .\ .\ , \qquad .\qquad .\qquad (71)$$

$$\nu_n\left(\frac{x}{q}\right)=\sum_{r=0}^{r=\infty}\left\{\nu_r\left(\frac{x}{q}\right)\mathrm{J}_{[n+r]}(vx)+\nu_{n+r}(x)\mathrm{J}_{[r]}(vx)\right\},$$

$$\lambda_0(x)=\lambda_0\left(\frac{x}{q}\right)\mathrm{J}_{[0]}(ux)+2\lambda_1\left(\frac{x}{q}\right)\mathrm{J}_{[1]}(ux)+\ .\ .\ .\ .\ .\ ,$$

$$\lambda_n(x)=\sum_{r=0}^{r=\infty}\left\{\lambda_r\left(\frac{x}{q}\right)\mathrm{J}_{[n+r]}(ux)+\lambda_{n+r}\left(\frac{x}{q}\right)\mathrm{J}_{[r]}(ux)\right\},$$

in which

$$u=\frac{aq^2}{1-q^2},\quad v=\frac{bq^2}{1-q^2}.$$

## Part III.

### Certain Δ-Equations and their Limiting Forms as Differential Equations.

### § 1. The General Hypergeometric Series.

It will only be possible in this section of the paper to state the forms of a few types of Δ-equations and their solutions, without entering into very detailed analysis.

$$\phi[x\Delta y]-\frac{1}{x}\psi[x\Delta y]=0 \qquad .\qquad .\qquad .\qquad .\qquad .\qquad (72)$$

has an infinite number of solutions of the form

$$y=\mathrm{A}\left\{x^a+\frac{\phi[a]}{\psi[a+1]}x^{a+1}+\frac{\phi[a]\phi[a+1]}{\psi[a+1]\psi[a+2]}x^{a+2}+\ .\ .\ .\ .\ .\right\},\qquad .\qquad .\qquad (73)$$

in which

$$\begin{aligned}\phi[x.\Delta y]\quad&\text{denotes}\quad \mathrm{C}_0y+\mathrm{C}_1x.\Delta y+\mathrm{C}_2x^2\Delta^2y+\ .\ .\ .\ .\ +\mathrm{C}_sx^s\Delta^sy,\\ \psi[x.\Delta y]\quad&\text{,,}\quad \mathrm{C}'_0y+\mathrm{C}'_1x\Delta y+\mathrm{C}'_2x^2\Delta^2y+\ .\ .\ .\ .\ +\mathrm{C}'_tx^t\Delta^ty,\end{aligned}$$

for, on operating with $\phi[x.\,\Delta y]$ on a series $\sum c_rx^{a+r}$,
we obtain

$$\sum x^{a+r}c_r\{\mathrm{C}_0+\mathrm{C}_1[a+r]+\mathrm{C}_2[a+r][a+r-1]+\ .\ .\ .+\mathrm{C}_s[a+r]\ .\ .\ [a+r-s+1]\}=\sum c_rx^{a+r}\phi[a+r].$$

Similarly operating with $\frac{1}{x}\psi[x.\,\Delta y]$ we obtain $\sum c_rx^{a+r-1}\psi[a+r]$, so that the solutions are furnished by the function (73), in which $a$ is any root of the indicial equation

$$\mathrm{C}'_0+\mathrm{C}'_1[a+r]+\mathrm{C}'_2[a+r][a+r-1]+\ .\ .\ .\ +\mathrm{C}'_t[a+r]\ .\ .\ .\ [a+r-t+1].$$

The general Hypergeometric Series of $q$-form is a special case of this equation and depends on the following theorem, which may be proved by induction :—

$$\text{If}\quad \Pi_n[a+m]\quad\text{denote}\quad \left(\frac{q^{a_1+m}-1}{q-1}\right)\left(\frac{q^{a_2+m}-1}{q-1}\right)\ .\ .\ .\ .\left(\frac{q^{a_n+m}-1}{q-1}\right),$$

$$\text{then}\quad \Pi_n[a+m]=\mathrm{A}_0+\mathrm{A}_1[m]+\mathrm{A}_2[m][m-1]+\ .\ .\ .\ .\ +\mathrm{A}_n[m][m-1]\ .\ .\ .\ [m-n+1],$$

in which the coefficients $A_0$, $A_1$, . . . . are independent of $m$ and are given by

$$A_r = \sum_{s=0}^{s=r} (-1)^s q^{\frac{1}{2}s(s-1)} \frac{\Pi[a+r-s]}{[r-s]![s]!} \quad . \quad . \quad . \quad . \quad (74)$$

For example,

$$A_3 = \frac{[a_1+3][a_2+3] \ldots [a_n+3]}{[3]!} - \frac{[a_1+2] \ldots [a_n+2]}{[2]![1]!} + q \frac{[a_1+1] \ldots [a_n+1]}{[1]![2]!} - q^3 \frac{[a_1] \ldots [a_n]}{[3]!},$$

the $q$-analogue of a well-known algebraical transformation.

If the $\Delta$ difference equation

$$\sum_{r=0}^{r=n} A_r x^r \Delta^r y - \sum_{r=0}^{r=m} B_r x^{r-1} \Delta^r y = 0,$$

in which $A_r$ is defined above,

$$\text{and} \qquad B_r = \sum_{s=0}^{s=r} (-1)^s q^{\frac{1}{2}s(s-1)} \frac{\Pi_m[\beta+r-s]}{[r-s]![s]!},$$

be compared with form (73) we see that on substituting $\sum c_r x^{m \times r}$,

$$\begin{aligned} \phi[m] &= A_0 + A_1[m] + A_2[m][m-1] + \ldots + A_n[m] \ldots [m-n+1], \\ &= \Pi_n[a+m], \text{ (as defined above)}. \end{aligned}$$

In the same way

$$\begin{aligned} \psi[m] &= B_0[m] + B_1[m][m-1] + \ldots + B_n[m][m-1] \ldots [m-n_1], \\ &= [m]\Pi_{n_1}[\beta+m-1], \end{aligned}$$

so that the solutions are given by a function

$$x^m + \frac{\Pi_n[a+m]}{[m+1]\Pi_{n_1}[\beta+m]} x^{m+1} + \frac{\Pi_n[a+m]\Pi_n[a+m+1]}{[m+1][m+2]\Pi_{n_1}[\beta+m]\Pi_{n_1}[\beta+m+1]} x^{m+2} + \ldots \ldots, \quad . \quad (75)$$

in which $m$ is any root of

$$[m]\Pi_{n_1}[\beta+m-1] = 0.$$

The principal roots are $0$, $1-\beta_1$, $1-\beta_2$, $1-\beta_3$, . . . . . , and corresponding to each of these $n_1$ principal roots there is doubly infinite system as in general

$$m = 1 - \beta_s + \frac{2r\pi i}{\log q + 2t\pi i} \qquad (r, t = 0, 1, 2 \ldots \text{ ad inf.}) \ (s = 0, 1, 2, 3 \ldots n_1).$$

The series from the principal root zero is

$$y = 1 + \frac{[a_1][a_2] \ldots [a_n]}{[1][\beta_1][\beta_2] \ldots [\beta_{n_1}]} x + \frac{[a_1][a_1+1] \ldots [a_n][a_n+1]}{[2]![\beta_1][\beta_1+1] \ldots [\beta_{n_1}][\beta_n+1]} x^2 + \ldots \ldots \quad . \quad (76)$$

From the principal root $1-\beta_s$ we shall have

$$y_s = x^{1-\beta_s} + \frac{[a_1-\beta_s+1] \ldots [a_n-\beta_s+1]}{[1][2-\beta_s][1-\beta_s+\beta_1] \ldots [1-\beta_s+\beta_n]} x^{2-\beta_s} + \ldots \ldots \quad . \quad . \quad (77)$$

The particular case

$$y = 1 + \frac{(q^\alpha - 1)(q^\beta - 1)}{(q-1)(q^\gamma - 1)} x + \ldots \ldots$$

is a solution of

$$[a][\beta]y + \{q^a[\beta+1]x + q^\beta[a]x - [\gamma]\}\Delta y + \{q^{\alpha+\beta+1}x^2 - q^\gamma x\}^2 y = 0. \quad . \quad . \quad (78)$$

## § 2. Special $q$-Difference Equations.

Three linear differential equations whose solutions enter into many interesting relations with one another are

$$x^2y'' + xy' + (x^2 - n^2)y = 0, \quad . \quad . \quad . \quad , \quad . \quad (79)$$

$$x^4y'''' + 6x^3y''' + (7 - 2m^2 - 2n^2)x^2y'' + (1 - 2m^2 - 2n^2)xy^1 + (x^2 - (m^2 - n^2)^2)y = 0, \quad . \quad (80)$$

$$x^4y'''' + 6x^3y''' + (7 - 2m^2 - 2n^2 + 4x^2)x^2y'' + (1 - 2m^2 - 2n^2)xy^1 - (m^2 - n^2)^2y = 0. \quad . \quad (81)$$

By means of (74) it is not difficult to construct the corresponding $\Delta$-equations: among the solutions of—

(79) is Bessel's Function $J_n(x)$,

of (80) is $J_{m,n}(x) = \sum(-1)^2 \dfrac{x^{m+n+2r}}{\Gamma(m+n+r+1)\Gamma(m+r+1)\Gamma(n+r+1)\Gamma(r+1)2^{m+n+2r}}$,

of (81) $\quad J_m(x) \times J_n(x) = \sum \dfrac{\Gamma(m+n+2r+1)}{\Gamma(m+n+r+1)\Gamma(m+r+1)\Gamma(n+r+1)} \quad \dfrac{x^{m+n+2r}}{\Gamma(r+1)2^{m+n+2r}}$.

The analogous $\Delta$-equations are

$$qx^2\Delta^2y + (1 - [n] - [-n])x\Delta y + (x^2 - [n][-n])y = 0, \quad . \quad . \quad . \quad (82)$$

$$q^6x^4\Delta^4y + q^3([1] + [2] + [3] + [m+n] + [m-n] + [n-m] + [-m-n])x^3\Delta^3y + cx^2\Delta^2y + bx\Delta y + x^2y + ay = 0, \quad (83)$$

$$q^6x^4\Delta^4y + q^3([1] + [2] + [3] + [m+n] + [m-n] + [n-m] + [-m-n]x^3\Delta^3y + (cx^2 + [2]^2x^4)\Delta^2y + bx\Delta y + ay = 0, \quad (84)$$

in which $\quad a = [m+n][m-n][n-m][-m-n]$,

$$b = [m+n+1][m-n+1][n-m+1][-m-n+1] - [m+n][m-n][n-m][-m-n],$$

$$c = \frac{[m+n+2] \ . \ . \ . \ . \ [-m-n+2]}{[2]!} - [m+n+1] \ . \ . \ . \ [-m-n+1] + q\frac{[m+n] \ . \ . \ . \ . \ [-m-n]}{[2]!},$$

which, when $q = 1$, reduce to the differential equations (79), (80), (81) respectively. We solve these $\Delta$-equations by substituting a series $\sum c_s x^{a+2s}$ and, in the case of equation (82), obtain an indicial equation

$$[a+n][a-n] = 0,$$

and an indicial function

$$f = c_0\left\{x^a - \frac{x^{a+2}}{[a+n+2][a-n+2]} + \ . \ . \ . \ . \ .\right\}.$$

The principal roots of the indicial equation are $+n$, $-n$. From these we obtain two principal solutions, which are not distinct when $n = 0$; also in case $n$ is an integer, one of the solutions becomes formally infinite. By a suitable choice of the arbitrary constant we write down the solution corresponding to the root $n$, as

$$y = \sum(-1)^r \frac{x^{n+2r}}{\{2n+2r\}!\,\{2r\}!} = J_q(n, x). \quad . \quad . \quad . \quad . \quad (85)$$

$\{2r\}! = [2][4][6] \ . \ . \ . \ [2r]$ in case $r$ is a positive integer. The form of $\{2n\}!$ when $n$ is not integral, I have discussed in *Proc. L.M.S.*, ser. 2, vol. ii. p. 195. The cases mentioned above, when one solution becomes formally infinite, or when the two solutions are not distinct, may be treated in the manner usual in finding solutions for differential equations in similar cases. The following is an example :—

## § 3. Solution corresponding to Hankel's $Y_n$.

Such a solution of equation (82) is

$$y = C\sum_{r=1}^{n-1}(-1)^r \frac{[2n]}{[2][4]\ldots[2r].[2-2n]\ldots[2r-2n]} x^{2r-n}$$
$$+ D\log x \sum_{r=1}^{\infty}(-1)^r \frac{q^{n+2r}x^{n+2r}}{\{2r\}!\,\{2n+2r\}!} \qquad (86)$$
$$- D\sum_{r=1}^{\infty}(-1)^r \left\{ \frac{q^2}{[2]} + \frac{q^4}{[4]} + \ldots \frac{q^{2r}}{[2r]} + \frac{q^{2n+2}}{[2n+2]} + \frac{q^{2n+4}}{[2n+4]} + \ldots + \frac{q^{2n+2r}}{[2n+2r]} \right\} \frac{x^{n+2r}}{\{2r\}!\,\{2n+2r\}!}.$$

The constants C and D not being independent, I do not propose to discuss such solutions of the $\Delta$-equations, but merely indicate that there are such solutions, as showing the parallel nature of the theory of these equations with the theory of ordinary differential equations. It is clear that Hankel's solution of Bessel's equation can be derived from the above in the limiting case $q = 1$.

The solution for $n = 0$, is

$$y = cJ_q(0, qx)\log x - c\sum_{s=1}^{=\infty}\left\{ \frac{2q^2}{[2]} + \frac{2q^2}{[4]} + \ldots + \frac{2q^{2s}}{[2s]} \right\} \frac{x^{2s}}{[2]^2[4]^2\ldots[2s]^2}.$$

I do not propose to discuss here the solutions obtained from the other roots of the indicial equation, namely those corresponding to

$$a = \pm n + \frac{2r\pi i}{\log q + 2s\pi i}, \ (r = 0, 1, 2, 3, \ldots).$$

## § 4. Solution of $q$-Difference Equation satisfied by $J_m . J_n$.

In the case of equation (80), on substituting $\sum c_s x^{a+2s}$ for $y$, we obtain an indicial equation

$$[m+n+a][m-n+a][m+n-a][-m-n+a] = 0,$$

and an indicial function

$$f = c_0\left\{ x^a + \frac{x^{a+2}}{[a+m+n+2][a-m+n+2][a+m-n+2][a-m-n+2]} + \ldots \right\},$$

and from the four principal roots of the indicial equation we derive four principal solutions, which, however, are not distinct in case $m$ and $n$ are both zero, and which become formally infinite in certain cases, so that special solutions involving $\log x$ would be necessary to replace these indeterminate forms. The four principal solutions, when distinct, will be denoted $J_q(m, n, x)$, $J_q(-m, n, x)$, $J_q(m, -n, x)$, $J_q(-m, -n, x)$, :

$$J_q(m, n, x) = \sum(-1)^r \frac{x^{m+n+2r}}{\{2m+2n+2r\}!\,\{2m+2r\}!\,\{2n+2r\}!\,\{2r\}!}. \qquad (87)$$

As before $\{2r\}!$ denotes $[2][4]\ldots[2r]$.

This function possesses many interesting properties, which will be given in § (4) *et seq.* It can be derived from the product of two functions $J_q(n, x)$.

In the case of equation (84), if we substitute $\sum c_s x^{a+2s}$ for $y$, we obtain an expression

$$\sum \left\{ [a+m+n+2s][a-m-n+2s][a+m-n+2s][a-m+n+2s]c_s x^{a+2s} - [2a+4s][2a+4s-2]c_s x^{a+2s+2} \right\},$$

so that the indicial equation is

$$[a+m+n][a-m-n][a+m-n][a-m+n]=0,$$

and the indicial function

$$f = c_0 \left\{ x^a + \frac{[2a+4][2a+2]}{[a+m+n+2][a-m-n+2][a+m-n+2][a-m+n+2]} + \ldots\ldots \right\}.$$

Choosing $c_0 = \dfrac{1}{\{2m\}!\,\{2n\}!}$, we obtain from the root $m+n$ of the indicial equation a principal solution

$$y = \sum \frac{\{2m+2n+4r\}!\, x^{m+n+2r}}{\{2m+2n+2r\}!\,\{2m+2r\}!\,\{2n+2r\}!\,\{2r\}!}, \qquad (88)$$

which I have shown * to be the product of two $q$ generalised Bessel functions, so we write

$$y_1 = c\mathrm{J}_q(m, x).\,\mathrm{J}_{q^{-1}}(n, x). \qquad (89)$$

The meaning of $\mathrm{J}_{q^{-1}}$ will require explanation. We have in (85)

$$\mathrm{J}_q(m, x) = \frac{x^m}{\{2m\}!}\left\{ 1 - \frac{x^2}{[2m+2][2]} + \frac{x^4}{[2m+2][2m+4][2][4]} - \ldots\ldots \right\}. \qquad (90)$$

If in this series we replace $q$ by $q^{-1}$ a new series is formed, viz.—

$$\sum (-1)^r \frac{x^{m+2r}}{\{2m+2r\}!\,\{2r\}!} q^{m^2+2r(m+r)},$$

which I denote $\mathrm{J}_{q^{-1}}(m, x)$. Both $\mathrm{J}_{q^{-1}}$ and $\mathrm{J}_q$ have a common region of convergence. In previous papers I have used the symbols $\mathrm{J}_{[m]}(x)$, $q^{m^2}\mathfrak{J}_{[m]}(x)$, to denote these series respectively, but I think it is better to use the notation $\mathrm{J}_q(m, x)$, as being both easier to print, and as showing explicitly the nature of the base. Moreover, it is apparent that the functions $\mathrm{J}_q$, $\mathrm{J}_{q^{-1}}$ are not distinct functions, but may be derived immediately, the one from the other, by inversion of the base $q$.

Now †

$$\mathrm{J}_q(n, x).\mathrm{J}_{q^{-1}}(m, x) = q^{n^2}\sum (-1)^r \frac{\{2m+2n+4r\}!\, x^{m+n+2r}}{\{2m+2n+2r\}!\,\{2m+2r\}!\,\{2n+2r\}!\,\{2r\}!}. \qquad (91)$$

$$\mathrm{J}_q(m, x)\mathrm{J}_{q^{-1}}(n, x) = q^{m^2}\sum (-1)^r \frac{\{2m+2n+4r\}!\, x^{m+n+2r}}{\{2m+2n+2r\}!\,\{2m+2r\}!\,\{2n+2r\}!\,\{2r\}!}. \qquad (92)$$

It is interesting to notice that

$$\frac{\mathrm{J}_q(n, x)\mathrm{J}_{q^{-1}}(m, x)}{\mathrm{J}_q(m, x)\mathrm{J}_{q^{-1}}(n, x)}$$

* *Proc. Roy. Soc.*, vol. lxxiv. p. 67.

† *Ibid.*, pp. 67–68.

is independent of $x$ and is equal to $q^{n^2-m^2}$, from which many curious results may be derived. We pass on, however, to give the four principal solutions of (84)—

$$\left.\begin{aligned} y_1 &= q^{m^2}\mathrm{J}_q(n,x)\mathrm{J}_{q-1}(m,x = q^{n^2}\mathrm{J}_q(m,x)\mathrm{J}_{q-1}(n,x),\\ y_2 &= q^{m^2}\mathrm{J}_q(n,x)\mathrm{J}_{q-1}(-m,x) = q^{n^2}\mathrm{J}_q(-m,x)\mathrm{J}_{q-1}(n,x),\\ y_3 &= q^{m^2}\mathrm{J}_q(-n,x)\mathrm{J}_{q-1}(-m,x) = q^{n^2}\mathrm{J}_q(-m,x)\mathrm{J}_{q-1}(-n,x),\\ y_4 &= q^{m^2}\mathrm{J}_q(-n,x)\mathrm{J}_{q-1}(m,x) = q^{n^2}\mathrm{J}_q(m,x)\mathrm{J}_{q-1}(-n,x), \end{aligned}\right\} \quad . \quad . \quad . \quad (93)$$

which may be expressed in a great variety of forms, as follows.

It is easy to establish a theorem for $q$ functions analogous to

$$e^{ix}\mathrm{J}_n(x) = \frac{x^n}{2^n\Gamma(n+1)}\left\{1 + ix + \frac{(2n+3)}{2(2n+2)}i^2x^2 + \frac{(2n+5)}{3!\,(2n+2)}i^3x^3 + \ldots\right\}, \quad . \quad . \quad (93a)$$

which is a well-known result in the theory of BESSEL's Function.

The corresponding result for an arbitrary power series, and the $q$-generalisation of the same, I propose to discuss in the supplementary paper.

The $q$-analogues of (93$a$) are

$$\left.\begin{aligned} \mathrm{E}_{q-1}(ix)\mathrm{J}_q(n,x) &= \frac{x^n}{\{2n\}!}\left\{1 + ix + \frac{[2n+3]}{[2][2n+2]}i^2x^2 + \frac{[2n+5]}{[3]![2n+2]}i^3x^3 + \ldots\right\},\\ \mathrm{E}_q(ix)\mathrm{J}_{q-1}(n,x) &= q^{n^2}\frac{x^n}{\{2n\}!}\left\{1 + ix + \frac{[2n+3]}{[2][2n+2]}i^2x^2 + \ldots\ldots\ldots\right\}, \end{aligned}\right\} \quad . \quad (94)$$

whence

$$\frac{\mathrm{J}_{q-1}(n,x)}{\mathrm{J}_q(n,x)} = q^{n^2}\frac{\mathrm{E}_{q-1}(ix)}{\mathrm{E}_q(ix)} = \frac{q^{n^2}}{\mathrm{E}_q(ix)\mathrm{E}_q(-ix)} \quad . \quad . \quad . \quad . \quad (95)$$

and so the solution $y_1$ can be expressed in the form

$$y_1 = q^{m^2+n^2}\frac{\mathrm{J}_q(n,x)\mathrm{J}_q(m,x)}{\mathrm{E}_q(ix)\mathrm{E}_q(-ix)}, \quad . \quad . \quad . \quad . \quad . \quad (96)$$

so that if we denote this solution of (84) by $\Phi_q(m, n, x)$, we have the following forms—

$$\Phi_q(m,n,x) = q^{m^2}\mathrm{J}_q(n,x)\mathrm{J}_{q-1}(m,x), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (97)$$

$$= q^{n^2}\mathrm{J}_q(m,x)\mathrm{J}_{q-1}(n,x), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (98)$$

$$= q^{m^2+n^2}\mathrm{J}_q(m,x)\mathrm{J}_q(n,x) \div \{\mathrm{E}_q(ix)\mathrm{E}_q(-ix)\}, \quad . \quad . \quad . \quad . \quad . \quad (99)$$

$$= q^{\frac{1}{2}(m^2+n^2)}\{\mathrm{J}_q(m,x)\mathrm{J}_q(n,x)\mathrm{J}_{q-1}(m,x)\mathrm{J}_{q-1}(n,x)\}^{\frac{1}{2}}, \quad . \quad . \quad . \quad . \quad (100)$$

$$= q^{m^2+n^2}\sum(-1)^r\frac{\{2m+2n+4r\}!\,x^{m+n+2r}}{\{2m+2n+2r\}!\,\{2m+2r\}!\,\{2n+2r\}!\,\{2r\}!}, \quad . \quad . \quad . \quad (101)$$

$$= q^{m^2+n^2}\left\{\sum(-1)^r\frac{\{4m+4r\}!\,x^{2m+2r}}{\{4m+2r\}!\,\{2m+2r\}!^2\,\{2r\}!}\right\}^{\frac{1}{2}} \times \left\{\sum(-1)^r\frac{\{4n+4r\}!\,x^{2n+2r}}{\{4n+2r\}!\,\{2n+2r\}!^2\,\{2r\}!}\right\}^{\frac{1}{2}}. \quad (102)$$

## § 5. RELATIONS BETWEEN VARIOUS SERIES.

Several interesting $q$ series may be deduced from these relations. By equating (97) and (98) we obtain

$$q^{m^2+n^2}\{\mathrm{J}_q(m,x)\mathrm{J}_{q-1}(m,x)\mathrm{J}_q(n,x)\mathrm{J}_{q-1}(n,x)\}$$

$$= q^{2m^2+2n^2}\left\{\sum(-1)^r\frac{\{2m+2n+4r\}!\,x^{m+n+2r}}{\{2m+2n+2r\}!\,\{2m+2r\}!\,\{2n+2r\}!\,\{2r\}!}\right\}^2. \quad . \quad . \quad . \quad (a)$$

which by (87) may be written

$$\left\{\sum(-1)^r\frac{\{4m+4r\}!\,x^{2m+2r}}{\{4m+2r\}!\,\{2m+2r\}!\,\{2m+2r\}!\,\{2r\}!}\right\}\left\{\sum(-1)^r\frac{\{4n+4r\}!\,x^{2n+2r}}{\{4n+2r\}!\,\{2n+2r\}!\,\{2n+2r\}!\,\{2r\}!}\right\} \quad (\beta)$$

$$=\left\{\sum(-1)^r\frac{\{2m+2n+4r\}!\,x^{m+n+2r}}{\{2m+2n+2r\}!\,\{2n+2r\}!\,\{2m+2r\}!\,\{2r\}!}\right\}^2,$$

whence, equating coefficients of $x^{2m+2n+2r}$,

$$\sum(-1)^r\frac{\{4m+4r\}!\{4n+4\nu-4r\}!}{\{4m+2r\}!\,\{4n+2\nu-2r\}!\,\{2m+2r\}!^2\,\{2n+2\nu-2r\}!^2\,\{2\nu-2r\}!\,\{2r\}!}$$

$$=\sum(-1)^r\frac{\{2m+2n+4\nu-4r\}!\,\{2m+2n+4r\}!}{2m+2n+2\nu-2r\}!\,\{2m+2n+2r\}!\,\{2n+2\nu-2r\}!\,\{2n+2r\}!}$$

$$\{2m+2\nu-2r\}!\,\{2m+2r\}!\,\{2\nu+2r\}!\,\{2r\}! \quad (\gamma)$$

in which $\{2r\}!=[2][4]\ .\ .\ [2r]$ and $[2r]=(q^{2r}-1)/(q-1)$. This identity holds when $m$ and $n$ are not integral, if $\{2n\}!$ be interpreted generally by a Basic-gamma Function. When $q=1$, the series reduce to special hypergeometric series ($x=1$), with eight elements in the denominator and two in the numerator of each term. It would be tedious to obtain further identities. I need mention only, that by considering such products as

$$\mathrm{J}_q(n\,,xt)\mathrm{J}_q(n\,,xt^{-1})\mathrm{J}_{q-1}((\nu\,,xt)\mathrm{J}_{q-1}(\nu\,,xt^{-1})$$

a great variety of relations can be obtained.*

## § 6. Recurrence Relations.

It would be tedious to give further analysis of these functions; so, to conclude the paper, I shall merely state certain recurrence and other relations satisfied by these functions

$$q^{2n}\mathrm{J}_q(m\,,n-1\,,x^2)+\mathrm{J}_q(m\,,n+1\,,x^2)=\frac{[2n]}{x^2}\Delta\mathrm{J}_q(m\,,n\,,x^2), \quad . \quad . \quad . \quad (\eta)$$

$$q^{2m}\mathrm{J}_q(n\,,m-1\,,x^2)+\mathrm{J}_q(n\,,m+1\,,x^2)=\frac{[2m]}{x^2}\Delta\mathrm{J}_q(m\,,n\,,x^2),$$

whence we deduce

$$\frac{q^{2n}\mathrm{J}_q(m\,,n-1)+\mathrm{J}_q(m\,,n+1)}{q^{2m}\mathrm{J}_q(n\,,m-1)+\mathrm{J}_q(n\,,m+1)}=\frac{[2n]}{[2m]}=\frac{(q^{2n}-1)}{(q^{2m}-1)}, \quad . \quad . \quad . \quad . \quad . \quad (\theta)$$

$$q^{2n}\mathrm{J}_q(m\,,n-1)+\mathrm{J}_q(m\,,n+1)=\frac{[2n]}{x^2}\left\{\mathrm{J}_q'(m\,,n)+x\frac{(q-1)}{2\,!}\mathrm{J}_q''(m\,,n)+x^2\frac{(q-1)^2}{3\,!}\mathrm{J}_q'''(m\,,n)+\ .\ .\ .\right\}, \quad (\kappa)$$

whence, in case $q=1$,

$$\mathrm{J}_{m,n-1}(x)+\mathrm{J}_{m,n+1}(x)=\frac{2n}{x}\mathrm{J}'(m\,,n\,,x).$$

In the theory of Bessel's Function

$$\left\{\frac{1}{x}\frac{d}{dx}\right\}^r x^{n+r}.\mathrm{J}_{n+r}=x^n\mathrm{J}_n.$$

* *Trans. R.S.E.*, vol. xli., pt. ii., p. 406.

The theorem analogous to this is

$$\left\{\left(x^{2n-1}\frac{d}{dx}\right)\left(x^{1-2n}\frac{d}{dx}\right)\right\}^r x^{m+n+r}\mathrm{J}_{m,\,n+r}=x^{m+n}\mathrm{J}_{m,\,n},$$

which in $q$-functions is

$$\{(x^{2n-1}\Delta)(x^{1-2n}\Delta)\}^r x^{m+n+r}\mathrm{J}_q(m,\,n+r)=x^{m+n}\mathrm{J}_q(m,\,n). \quad . \quad . \quad . \quad (\lambda)$$

Other $\Delta$ equations are

$$x\frac{d}{dx}\left\{x^{m+n}\mathrm{J}_{m,\,n}\right\}+x^{-1}\frac{d}{dx}\left\{x^{m+n+2}\mathrm{J}_{m+1,\,n+1}\right\}=(2m+2n)x^{m+n}\mathrm{J}_{m,\,n} \quad . \quad . \quad (\mu)$$

$$x\Delta\left\{x^{m+n}\mathrm{J}_q(m,\,n,\,x)\right\}+x^{-1}\Delta\left\{x^{m+n+2}\mathrm{J}_q(m+1,\,n+1,\,x)\right\}=[2m+2n]\left(\frac{x}{q}\right)^{m+n}\mathrm{J}_q(m,\,n,\,qx). \quad (\nu)$$

If

$$\Delta\{x^{m+n}\mathrm{J}_q(m,\,n)\}=x^{m+n-1}\phi_q(m,\,n,\,x), \quad . \quad . \quad . \quad . \quad (\rho)$$

then

$$\phi_q(m,\,n,\,x)+\phi_q(m+1,\,n+1,\,x)=\frac{[2m+2n]}{q^{m+n}}\mathrm{J}_q(m,\,n,\,qx),$$

from which, of course, various series may be obtained by repetition.

# XII.—The Evolution of the Eyebrow Region of the Forehead, with Special Reference to the Excessive Supraorbital Development in the Neanderthal Race. By Professor D. J. Cunningham, F.R.S. (With Three Plates.)

(MS. received 23rd March 1908. Read 24th June 1907. Issued separately June 16, 1908.)

One of the most striking features of the famous Neanderthal cranium consists in the strong projection which is exhibited in the glabellar and the supraorbital or eyebrow regions of the frontal bone. This character is rendered all the more important from the fact that all the specimens which have been collected since the Neanderthal cranium was discovered (1857), and which have been shown to belong to the same remote geological period, possess the same, or at least very much the same, remarkable prominence in the eyebrow region. These specimens are not very numerous, but, inasmuch as they represent the earliest remains of man with which we are acquainted, they possess a very special interest. In addition to the Neanderthal cranium, the group includes the two Spy crania, the Gibraltar skull, and the recently discovered Krapina remains. The Krapina remains are in a very fragmentary condition, but they apparently consist of portions of the skeletons of ten individuals, and the frontal bones all present the character in question.

It is curious that, although all of the many observers who have written upon the Neanderthal race have dwelt upon the supraorbital projection and have recognised in it one of the leading peculiarities of the group, no one, with the exception of SCHWALBE, has subjected the eyebrow region to a searching and critical examination. In his recent important papers upon the so-called *Pithecanthropus erectus* and on prehistoric man, SCHWALBE has thrown much light upon the value to be attached to the eyebrow projection, and has stimulated further research in the same field (5 to 11).*

In the present investigation I have had the great advantage of having been afforded the privilege of studying the splendid collection of anthropoid and lower ape skulls in the British Museum. This privilege I owe to the kindness of Mr OLDFIELD THOMAS, to whom I cordially offer my most grateful acknowledgments. To the British Museum specimens must be added the numerous anthropoid and lower ape crania in the Museum of the University of Edinburgh, which were also at my disposal. The full range of the investigation, in so far as the ape is

* Professor SCHWALBE has had the inestimable advantage of having recently been permitted to study at his leisure and in his own laboratory the Neanderthal remains. These he has described with great care (8), and has placed in the hands of other observers particulars in regard to these specimens of very great value.

concerned, can best be appreciated by the following list of the specimens which have come under my notice :—

| | | |
|---|---|---|
| Gorilla | 18 | |
| Chimpanzee | 33 | |
| | | 10 young |
| | | 23 adult |
| Orang | 46 | |
| | | 19 young |
| | | 27 adult |
| Gibbon | 27 | (including 9 species) |
| Semnopithecus | 18 | ( „ 5 „ ) |
| Nasalis | 4 | |
| Colobus | 44 | |
| Cercopithecus | 33 | |
| Cercocebus | 20 | |
| Macacus | 27 | (including 15 species) |
| Cynopithecus | 1 | |
| Cynocephalus | 50 | |
| Cebus | 12 | |

The large collection of human crania, including somewhere about 1500 specimens, in the Museum of the University of Edinburgh has more than sufficed for my purpose. I do not pretend to have examined all of these skulls from this point of view. I have chiefly directed my attention, for reasons that will be afterwards apparent, to the group of Australian crania (130 in number), and of these I selected the Victoria and Queensland specimens for special study.

## Degree of Projection of the Glabellar Part of the Frontal Bone.

Schwalbe estimates the extent and degree of projection of the glabellar part of the eyebrow-region by measuring by the callipers the chords of the glabellar and cerebral curves or arcs of the frontal bone, and expressing the former as a percentage of the latter, thus :

$$\frac{\text{Glabellar chord} \times 100}{\text{Cerebral chord}}.$$

When dealt with in this way, the Neanderthal cranium gives an index of 44·2, and the Spy cranium No. 1 an index of 41·5. According to Schwalbe, the index in recent man rarely reaches 30, and varies between the limits of 21·4 and 31·8 (8, p. 29).

A New South Wales Australian cranium (xxix. B. 1) in the ethnological collection of the University gives an index of 30·7, and another Australian skull from the Riverina district (xxix. B. 12), with a still more prominent glabellar region, yields an index of 34. But I believe that even this index may be exceeded. Recently I received from Dr W. Ramsay Smith, of Adelaide, the head of an aboriginal Australian named Boco, in which there was an excessive development of the glabellar and supraorbital regions of the forehead (2). It had been carefully preserved by formalin injection, and measured over the soft parts the index reached the high figure of 52·3. Of course this cannot

be taken as being comparable with those indices obtained from measurements of the skull, but there is reason to believe that if the calvaria of Boco were denuded of the scalp covering it would give an index at least as high as that of the Neanderthal cranium.

But what is the value of this glabello-cerebral index of SCHWALBE? Can we rely upon it giving a true and proper idea of the relative extent and degree of projection of the pars glabellaris of the cranium? I do not think that we can, and I look upon the figures given above as being of little value, and in certain respects misleading. If the mesial length of the frontal bone, measured either by the tape or the callipers, from the nasion to the bregma were relatively (even approximately) the same in different skulls, some reliance might be placed on the index; but when we find in three skulls so similar in the degree of glabellar projection as the Neanderthal, Spy 1, and Riverina the total frontal length, as ascertained by the tape, so very different as 133 mm., 120 mm., and 147 mm. respectively, it is evident that in these cases the index expresses variations in the length of the cerebral part of the frontal bone more than variations in the length of the glabellar part. Indeed, no index is necessary. The proper comparison to institute is one between the absolute measurements of the glabellar part made by the tape over its curvature from nasion to ophryon in different skulls. When this is done in the crania under consideration we obtain the following figures, and from these we can best realise the extent and degree of glabellar projection:—

| | |
|---|---|
| New South Wales cranium (xxix. B. 1) | 31 mm. |
| Spy No. 1 „ | 40 „ |
| Riverina skull (xxix. B. 12) | 41 „ |
| Neanderthal cranium | 43 „ |
| Boco (over scalp tissues) | 50 „ |

We are thus enabled to conclude that the high degree of glabellar development which is seen in the Neanderthal group, and which in it constitutes a distinct and definite racial character, may nevertheless be attained as an occasional variation in certain individuals of other races—notably the Australian race.

GIUFRIDA-RUGGERI (4), in a suggestive and well-reasoned paper, likewise expresses his dissatisfaction with SCHWALBE's glabello-cerebral index. He refers to the variability in the position of the bregma due to differences in the form of the coronal suture,* and then he goes on to remark: "Even the position of the nasion varies according as the fronto-nasal suture is semilunar, triangular, or horseshoe-shaped, and this exercises an influence on the length of the glabellar chord. I have obtained higher indices in certain Melanesian skulls in which the bregma was not much displaced backwards." He gives five examples in which the index varied from 30·2 to 33·3, and then remarks: "Finally, in the skull 760, which is one of the most interesting in the Anthropological Museum in Rome, I obtained an index of 39·7, to which I would draw the attention of Professor SCHWALBE."

* This is merely another way of stating that the variations in the position of the bregma are due to variations in the extent of the frontal field of the cranial wall.

But while the glabellar region in individual cases in recent man may assume proportions quite as great as those which are seen within the Neanderthal group, I would not have it supposed that I attach undue importance to the agreement in this respect. Certain suggestive and significant points of difference will be brought out in the course of this paper. To one of these we may refer at the present time. The depression above the glabellar and supraorbital regions in the Neanderthal and Spy crania is much more extensive than in the case of any recent skull or in the skulls of any other prehistoric race. This constitutes a marked and highly important distinction, and one which brings the Neanderthal type of cranium into closer relation with that of the chimpanzee and the gorilla. SCHWALBE fully recognises the significance of this character. The forward expansion of the cerebral part of the frontal bone in response to the increased develop-

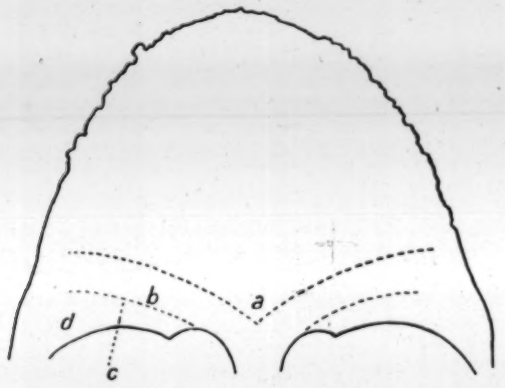


FIG. 1.—This figure is reproduced from SCHWALBE'S article upon "Das Schädelfragment von Brüx, etc." (p. 109). It is an outline representation of the supraorbital region of a mandrill (*Cynocephalus mormon*).

*a*. Fossa supraglabellaris.
*b*. Arcus superciliaris.
*c*. Groove between *b* and
*d*. Arcus supraorbitalis.

ment of the brain in recent man has to a large extent obliterated this highly suggestive cranial feature in the Neanderthal forehead.

## FORM AND MORPHOLOGICAL CONSTITUTION OF THE EYEBROW REGION.

SCHWALBE has given a large amount of attention to the form and morphological constitution of the eyebrow region of the forehead in the Neanderthal race (6, 8, 10), and although I cannot accept certain of the conclusions at which he has arrived, it should be recognised that in this field of work he has broken new ground and has added greatly to our knowledge of the evolution of this part of the skull. He holds that the supraorbital region in the Neanderthal group is distinctive of that race, and that it differs in form and mode of construction from the same region in any other race, either past or present. He elaborates this point with much ability in several of his writings, and gives this feature a leading place amongst the characters which are peculiar to the crania of that primitive group.

In briefly stating the views of SCHWALBE, I shall follow the description which he gives

in his recent paper on "Das Schädelfragment von Brüx und verwandte Schädelformen" (10). He takes as a type the condition presented by the frontal bone of the mandrill (*Cynocephalus mormon*), and he recognises, above the nasion and the margin of the orbital opening, two regions, viz. (1) the superciliary ridge (arcus superciliaris), which extends upwards and outwards from the glabellar swelling (fig. 1, *b*); and (2) a lateral area situated below and to the outer side of the superciliary ridge. This area he terms the arcus supraorbitalis (fig. 1, *d*). It stretches from the supraorbital notch to the

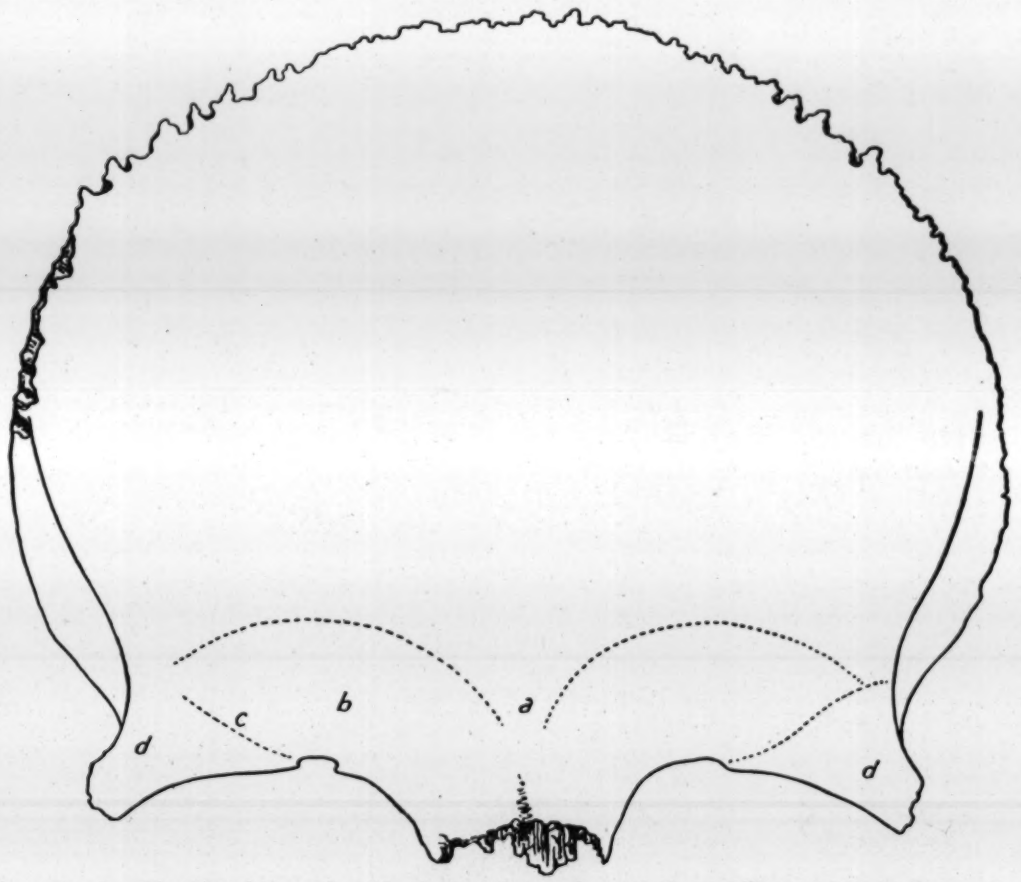


FIG. 2.—The frontal bone of an Alsatian, with strongly marked superciliary eminences (from SCHWALBE, "Das Schädelfragment von Brüx, etc.," p. 110).

*a*. Fossa supraglabellaris.
*b*. Superciliary eminence.
*d*. Trigonum supraorbitale.
*c*. Groove between *b* and *d*.

external angular process of the frontal bone, and forms a three-sided field between the superciliary ridge above and the margin of the orbital opening below.

SCHWALBE further states that the same parts, in very much the same relationship to each other, may be seen in the eyebrow region of recent man, and he gives outline sketches of the frontal bone of a mandrill and of an Alsatian to illustrate this point. These figures I have taken the liberty to reproduce, so as to make his position on this matter absolutely clear (figs. 1 and 2). In both of these drawings it can be seen that there is an arcus superciliaris (*b*) and an arcus supraorbitalis (*d*), and that these are separated from each other by an oblique furrow, the sulcus supraorbitalis (*c*), which ascends from the supraorbital notch in an outward and upward direction.

The arcus supraorbitalis (*d*) by its lower border forms the greater part of the upper portion of the margin of the orbital opening, and in the recent human skull, according to SCHWALBE, it presents a depressed or flattened field. For this reason he suggests that it should be termed the planum or trigonum supraorbitale. The latter name, in the vast majority of recent human skulls, admirably expresses its general characters.

To the inner side of the supraorbital notch the margin of the orbital opening is formed by the inner portion of the superciliary ridge (arcus superciliaris) as it runs into the glabella. The supraorbital notch, therefore, is an important landmark; to its inner side the orbital margin is formed by the superciliary ridge; to its outer side it is formed by the lower border of the trigonum supraorbitale.

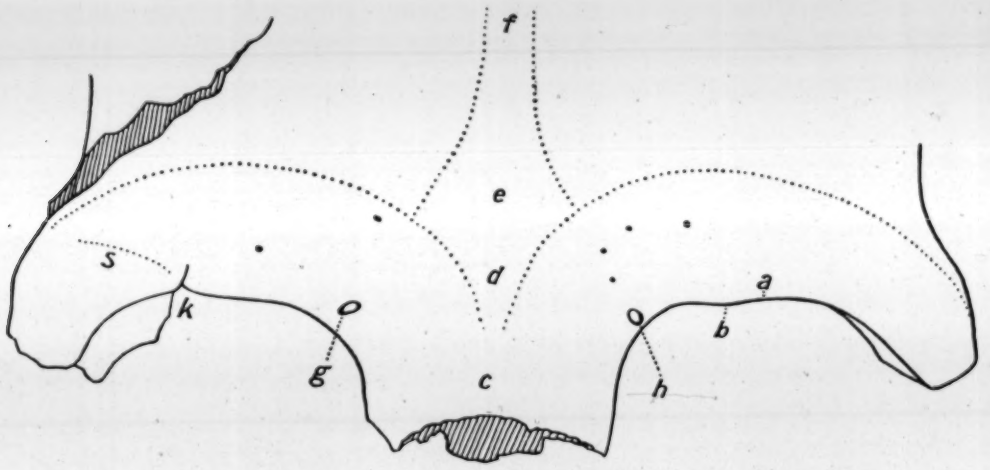


FIG. 3.—Outline sketch of the supraorbital region of the Neanderthal cranium, taken from SCHWALBE's article on "Der Neanderthalschädel," p. 11.

*a*. Slight notch (supraorbital notch (?)).
*b*. Slight elevation on the left supra-orbital border.
*c*. Glabella.
*d*. Fossa supraglabellaris.
*e*. Eminentia supraglabellaris.
*f*. Median frontal ridge.
*g* and *h*. Foramina supratrochlearia.
*k*. Notch on right supraorbital border (supraorbital notch).

Such is SCHWALBE's account of the supraorbital region in recent man and in all primitive races, with the single exception of the Neanderthal race. There cannot be a doubt that the description accurately conveys the condition which is present in the majority of recent skulls, and that it reproduces the type which exists not infrequently in the young mandrill and many other different forms of ape. But SCHWALBE falls into error in asserting (1) that this is the only form of supraorbital region which exists in recent man; and (2) that the form of the eyebrow region which is seen in the Neanderthal, Spy, and Krapina crania is never met with in the crania of the present day.

In the Neanderthal cranium the supraorbital region is developed in the form of a strongly projecting continuous arch, which extends from the glabella to the external angular process (fig. 3). I am in complete agreement with SCHWALBE as to the constitution of this arch. The superciliary eminence and the trigonum supraorbitale have

become fused together so as to produce the striking arcuate elevation which distinguishes the eyebrow region in this cranium. Further, the term, torus supraorbitalis, which SCHWALBE suggests should be applied to it appears to me to be both useful and appropriate. Indeed, I only take exception to the assertion that, while in the Neanderthal cranium the two elements, the arcus superciliaris and the trigonum supraorbitale, run together and become fused into one continuous arch, these elements invariably remain separate in the crania of recent man.

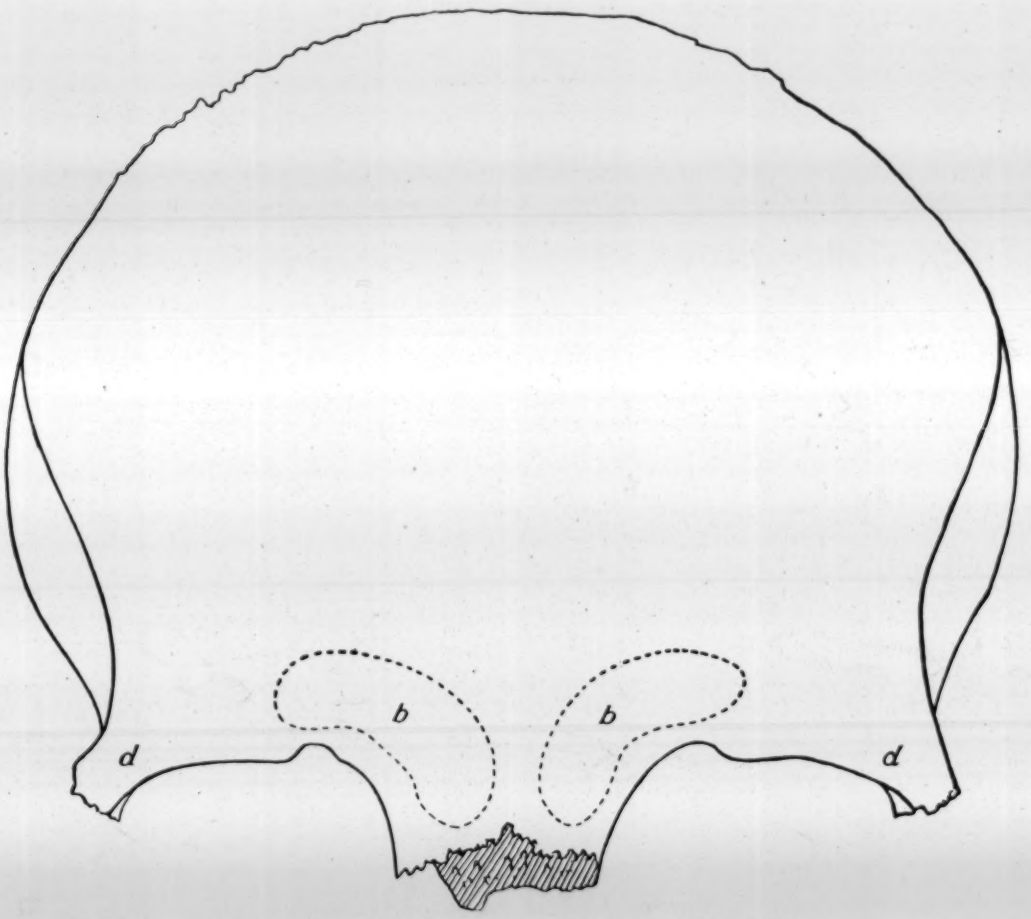


FIG. 4.—Outline tracing of the frontal region of a French skull.
*b*. Arcus superciliaris. *d*. Trigonum supraorbitale.

In studying the eyebrow region in man and the ape it will be convenient to look upon the elements which are typically present as being three in number. These elements are represented by the following parts :—

1. The supraorbital margin or the frontal part of the rim of the orbital opening.
2. The superciliary arch or ridge.
3. The trigonum supraorbitale.

According to the manner in which these three elements are arranged with reference to each other, three types of the supraorbital region may be distinguished.

At the same time, however, it should be recognised that the three elements are not always present, either separate and distinct from each other, or in combination with each

other. There are certain ape crania in which the arcus superciliaris is absent, and in every large collection of human crania a few specimens will be found in which the same deficiency may be observed. In the latter the glabella and the region above the orbital opening are flat and vertical, and similar in appearance to what is seen in the forehead of the European child before the superciliary ridges and the frontal air sinuses are developed. This form of supraorbital region would seem to occur most frequently in certain African races. The only skull in the University collection in which there is absolutely no trace of a superciliary eminence or of a glabellar fulness is that of a male Nupé from

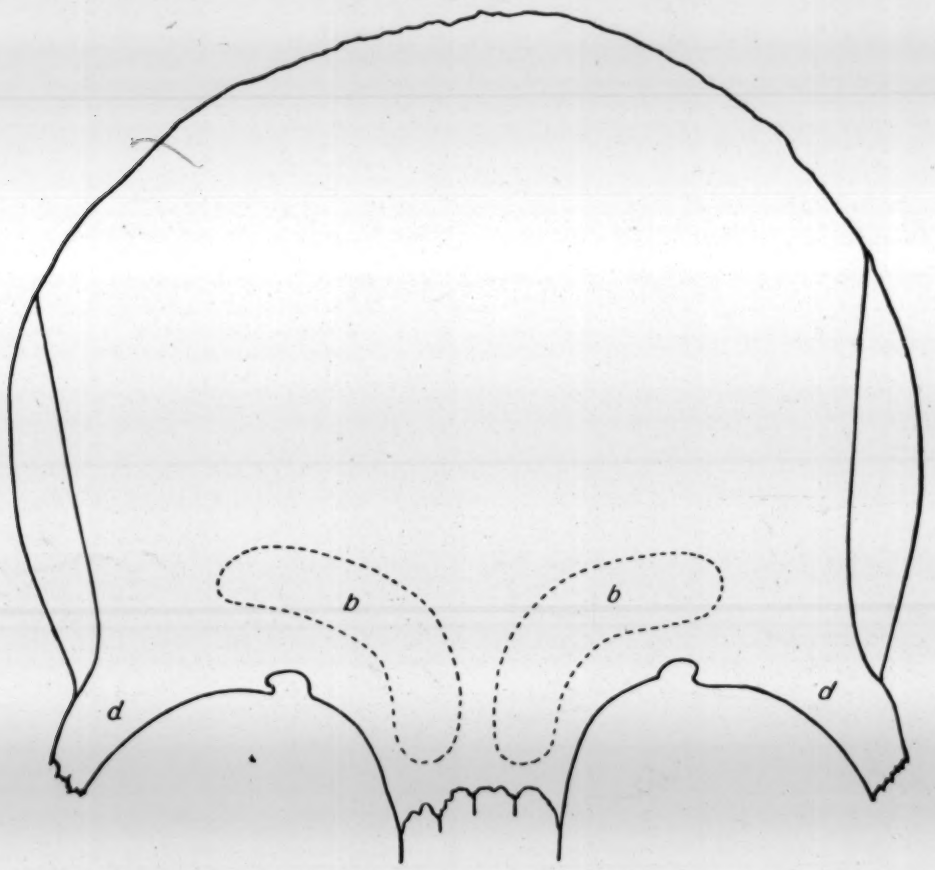


FIG. 5.—Frontal region of a Kham warrior from Thibet (Museum, No. xxiv. A. 2).
*b*. Superciliary eminence. *d*. Trigonum supraorbitale.

Nigeria which I received from my friend and former pupil, Dr HOWARD ENSOR. There are several specimens (*e.g.* an Andaman skull, the skull of an adult Negress, a West African skull presented to me by my colleague Professor H. LITTLEJOHN, the skull of a Ba-Mbala native given to me by Mr E. E. TORDAY, etc., etc.) which at first sight appear to be devoid of glabellar and superciliary eminences; but when these specimens are inspected in a proper light it is noticed that there is a general fulness in this region, and perhaps a scarcely perceptible indication of the arcus superciliaris. In all there is an appreciable flattening in the region of the trigonum supraorbitale.

TYPE I.—There are many human crania in many different races in which the three elements of the supraorbital region are distinct and separate. The same also may be observed in certain species of ape.

The *supraorbital margin* extends in a continuous and arch-like manner from the fronto-malar suture on the outer side to the fronto-maxillary suture on the inner side. It is divided into a long outer part and a shorter inner portion by the supraorbital notch. The outer portion is a projecting and sharply defined edge; the inner part, quite distinct from the superciliary arch, sweeps downwards immediately in front of the trochlear pit, and although much less prominent than the outer part is yet quite obvious (fig. 4).

The *superciliary ridge* or *arcus superciliaris* is a semilunar, smooth elevation which lies above the inner part of the inner portion of the supraorbital margin (fig. 4). Its inner end curves downwards into the glabella, and is separated from the corresponding eminence of the opposite side by a narrow, shallow median depression; its outer end fades away as it approaches the trigonum supraorbitale.

The *trigonum supraorbitale* lies to the outer side of the superciliary eminence. It is a triangular depressed field, with its apex at the fronto-malar suture, which is included between the outer part of the margo supraorbitalis and the anterior prominent part of the temporal ridge.

Fig. 4 is taken from a lecture specimen of the frontal bone which I am in the habit of using for class purposes. Fig. 5 is the frontal bone of a Kham warrior from Thibet, in which Type I. of the supraorbital region is particularly well marked. Owing to the somewhat unusual length and strongly curved character of the superciliary arches, the supraorbital region in this skull presents a striking appearance. The trigonum supraorbitale is very depressed.

This type of eyebrow region does not appear to be distinctive of, nor indeed more frequently present in, any one race more than another. It occurs in most, if not in all, recent races, and even amongst Australian skulls it is not infrequently met with, as will be seen from the following figures:—

*Number of Times present in a Group of* 25 *Australian Skulls.*

| | | |
|---|---|---|
| Natives of Victoria | — 8 males . . . | 1 |
| | 5 females . . | 2 |
| Natives of Queensland | —10 males . . . | 1 |
| | 2 females . . | 0 |

In this small group of Australian skulls, therefore, Type I. of the eyebrow region occurred four times, or in 16 per cent. of the specimens.

This type of the supraorbital region is also seen in certain apes, although probably in no case is it to be regarded as distinctive of any particular species. Still, it should be noted that it was present in a very definite manner in each of the three specimens of *Macacus cyclops* which I had the opportunity of studying.

The specimens in which it occurred were the following :—

| | |
|---|---|
| *Macacus cyclops* . . . . | 3 times |
| *Macacus nemestrinus* . . . . | 4 „ |
| *Macacus rhesus* . . . . | 2 „ |
| *Macacus speciosus* . . . . | 1 „ |
| *Cercopithecus* . . . . | 3 „ |
| *Cercocebus* . . . . . | 1 „ |
| *Cynocephalus niger* . . . . | 1 „ |
| *Cynocephalus porcarius* . . . | 1 „ |

The skull of a young specimen of *Macacus cyclops* is figured in Pl. I., fig. 14. It exhibits a somewhat unusual condition, and the supraorbital region in two other skulls belonging to the same species presented a similar appearance. A slightly raised oval field above and behind the glabella and inner part of the supraorbital margin represents the superciliary eminence. It is quite isolated, and stands apart from the glabella and the margo supraorbitalis.

The skull of an older specimen of macaque monkey (*Macacus rhesus*) is seen in Pl. I., fig. 15. In this specimen the three elements of the eyebrow region are also distinct from each other, but the superciliary projection is very different in form and in its degree of prominence. It forms a pronounced, elongated eminence which runs outwards above the margin of the orbital opening, and presents a different texture from that of the surrounding bone. Its outer extremity runs into the trigonum supraorbitale and reaches the anterior part of the temporal ridge, with which it in part fuses. Throughout its whole length it is separated from the margo supraorbitalis by a strongly marked groove, whilst its inner end remains distinct and does not run into the glabella nor fuse with its fellow of the opposite side.

A somewhat similar arrangement is seen in the skull of an adult specimen of the black ape of the Celebes (*Cynocephalus niger*). The superciliary eminence is in the form of a sharply marked ridge placed above the margin of the orbital opening, and separated from it by a deep sulcus. Its outer end remains free and ends in the trigonum supraorbitale. In the median line there is a small rounded prominence which lies between the inner ends of the two superciliary ridges, and probably represents the glabella.

In the young chacma baboon (*Cynocephalus porcarius*) we sometimes meet with a condition which presents a strong resemblance to what is seen in cases where Type I. of this region is present in the human skull (Pl. I., fig. 17). The strongly marked superciliary eminences are semilunar in outline and curve upwards and outwards from the region of the glabella to the temporal ridge on either side. The eminences remain distinct from each other, but turn downwards into the glabella. A broad, shallow groove separates the superciliary ridge from both the inner and outer parts of the margo supraorbitalis.

It must be clearly understood that I do not put forward these specimens, all of which fall clearly within the limits of Type I., as being characteristic of the species of ape to which they belong. As in the case of the same form of eyebrow region in the

human skull, they must be looked upon as being merely peculiar to certain individuals and as occurring sporadically in several different genera and species of ape.

Anyone who studies the ape skull can readily satisfy himself that within one species several different forms of the supraorbital region may be encountered. To some extent this is apparently the result of the vagaries of individual development, but it is probably more frequently due to changes which occur with the advance of age. As adult life is approached, there appears to be a tendency towards a partial or complete fusion of the three elements, and thus amongst the apes the same individual may present very different types of eyebrow region at different periods of life.

Type II.—In Type II. are included those skulls which exhibit that condition of the supraorbital region which Schwalbe has described as being peculiar to recent man, and also to the mandrill and other species of ape. The superciliary projection has coalesced with the part of the supraorbital margin which lies to the inner side of the supraorbital notch. On the outer side of the notch the eminence extends outwards with a varying degree of prominence and for a varying distance towards the trigonum supraorbitale. From the latter it is separated by a faint groove which ascends obliquely upwards and outwards from the supraorbital notch. The trigonum supraorbitale, which varies in its extent according to the degree of development of the arcus superciliaris, is, as a rule, depressed and flattened. This form of the supraorbital region occurs in all races, past and present, with the exception of the Neanderthal race, and is undoubtedly the condition which is most distinctive of man.

In the group of 25 Australian skulls to which I have already referred, Type II. of the supraorbital region occurred no less than 18 times, or in 72 per cent.

| | | |
|---|---|---|
| Natives of Victoria | — 8 males . . . | 5 times |
| | 5 females . . . | 3 „ |
| Natives of Queensland | —10 males . . . | 8 „ |
| | 2 females . . . | 2 „ |

As Schwalbe has shown, Type II. of the supraorbital region also appears in the mandrill (6 and 10), but the form which he has figured (fig. 1, p. 286) only occurs in young specimens. In the adult skull there is a tendency towards the coalescence of the different elements and the formation of a torus which is morphologically equivalent to what is seen in the gorilla and the chimpanzee. Still, this is not by any means the invariable result of advancing age in the mandrill. In the largest and most characteristic skull of this ape in the British Museum, the form presented by the supraorbital region falls clearly within Type II., although the massive superciliary eminence is restricted to the inner part of the region and does not stretch outwards in the form of an elongated ridge, as in the young specimens of the same species.

It is in the genus Cynocephalus that we find the closest approximation to Type II. as it is exhibited in the human skull. Probably this is the only group of apes in which this type of eyebrow region is almost invariably present. Young specimens may be found in which Type I. occurs (Pl. I., fig. 17); these are rare. Again, as age advances

there is undoubtedly a tendency for the elements of the region to fuse together to form a torus; but in the fifty specimens I have examined I have not seen a skull in which the coalescence is complete. There is always a trace of the groove which intervenes between the superciliary eminence and the trigonum supraorbitale. Figs. 18 and 19, Pl. I., represent the usual appearance which is presented in this genus. In the middle line the two superciliary arches are completely fused to form the glabellar eminence, and here also they coalesce with the part of the orbital margin which lies to the inner side of the supraorbital notch. From the glabella the two superciliary ridges arch outwards like the two limbs of the letter Y, and, gradually tapering, each ends in the neighbourhood of the temporal ridge. A strongly marked groove separates the superciliary eminence from the trigonum supraorbitale. The term "trigonum" is hardly appropriate for the part of the region which lies below and to the outer side of this groove. It is true that it is a somewhat triangular area, but it is not flattened and depressed as is usually the case in the human skull; it is prominent, ridge-like, and highly curved in accordance with the curvature of this part of the orbital opening. This may be regarded as an approach to the condition termed by SCHWALBE a "torus supraorbitalis." By the disappearance of the intervening groove and the consequent coalescence of the superciliary eminence and the trigonum supraorbitale, the form distinctive of the Neanderthal race, the gorilla, chimpanzee, etc., would be produced.

The condition seen in the New Hebrides skull figured in Pl. III., fig. 23, presents a striking resemblance to the form of supraorbital region which we have described as distinctive of the baboon. Two points of difference, however, are noticeable. The two superciliary arches have drawn away from each other in the glabellar region, and their inner ends are separated from each other by a shallow median groove. This is due to the broadening of the forehead in man, and the coincident widening of the glabellar region and of the interval which separates the orbits. In the baboon the narrow forehead is associated with a narrow glabella and a narrow root of the nose, and thus the superciliary ridges are brought together in the middle line. The second point of difference is in the trigonum supraorbitale. This area is flat and depressed in the New Hebridean skull, although there is seen a tendency for the outer part of the supraorbital margin to form an arched prominence as in the baboon.

Although not distinctive of any other group of apes, Type II. frequently occurs in individuals of other genera and species. I have noted its presence in the following specimens:—

| | |
|---|---|
| *Semnopithecus* (in two species, viz. *auratus* and *cristatus*) . . . | 4 times |
| *Nasalis lanatus* . . . . . | 1 „ |
| *Cercopithecus* . . . . . | 5 „ |
| *Cercocebus* . . . . . | 5 „ |
| *Macacus* (in eight different species) . . . . . | 14 „ |
| *Presbytes maurus* . . . . . | 1 „ |
| *Cebus* (in four different species) . . . . . | 5 „ |

In certain of the nine specimens entered in the above list as belonging to the genera

Semnopithecus and Cercocebus the fusion of the three elements of the supraorbital region was very nearly complete, but in the region of the trigonum the superciliary element showed as a distinct ridge above the outer part of the orbital margin. In these cases the supraorbital notch fails as a guide to the line of separation between the superciliary and other parts of the region.

SCHWALBE gives a careful and accurate account of the supraorbital region in the cranium of *Pithecanthropus erectus*, in so far as this can be studied in the plaster cast of the specimen, and he supplements his remarks by a drawing. I have had the advantage of being able to examine two casts of this cranium, one of which was presented to me by Dr EUGENE DUBOIS when he visited Dublin, and another which he gave to Sir WILLIAM TURNER. Both of these specimens are in the Anatomical Museum of the University of Edinburgh. They are sharp and excellent casts, and they agree in every particular with SCHWALBE's description. I am thus able to confirm SCHWALBE's view that the eyebrow region presents the form which I have included under Type II. It should be noted, however, that the fusion between the superciliary and the supraorbital elements is very nearly complete, and the condition is one which closely corresponds to that which is frequently seen in the aged Anubis baboon. Indeed, from the appearance of the eyebrow region I think we may conclude with some degree of certainty that the cranium of *Pithecanthropus erectus* is that of an aged individual.

As SCHWALBE points out, it is an important and significant fact that it is to the baboon, much more than to the gorilla or chimpanzee, that *Pithecanthropus erectus* shows a resemblance in this respect (6).

TYPE III.—In this form of the supraorbital region all the three elements which enter into its formation become fused together so as to constitute a continuous arch, the torus supraorbitalis, which bounds the orbital opening above and forms a varying amount of the fore-part of the roof of the orbital cavity. This arch extends from the glabella to the fronto-malar suture, and in its typical condition it shows no trace of the constituent elements of which it is composed, so completely have these become blended the one with the other. Of such a nature is the supraorbital region in the adult chimpanzee, in the gorilla, and in a large number, if not the majority, of the lower apes of the Old World. Still, it is not correct to suppose that even in the gorilla and the chimpanzee this is the only condition of the eyebrow region which may be present, and that there never occurs an approach to the form distinctive of Type II. In young specimens of the chimpanzee the superciliary eminence, although fused with the supraorbital torus and not marked off on its outer side by any distinct groove, is yet as a rule easily discernible, not only by the greater degree of prominence of this part of the arch, but also by a difference in its texture. The same also may be occasionally seen in the adult chimpanzee. In such cases the supraorbital notch, which SCHWALBE takes as the demarcation between the supraorbital and superciliary elements, fails to be a true guide. The superciliary element extends outwards in the torus far beyond this point. In the beautiful illustrations of anthropoid crania which are given by SELENKA,

there is the figure of the skull of a young female gorilla in which the superciliary element of the torus supraorbitalis is distinctly seen (12, fig. 112, p. 102). It is still more evident in the skull of an adult male chimpanzee in the Anatomical Museum of the University of Edinburgh. The photograph of this skull is given in Pl. I., fig. 15. Transition forms between Type II. and Type III. of the supraorbital region are thus met with in both the chimpanzee and the gorilla.

Of the nineteen skulls of the adult chimpanzee which I had the opportunity of studying in the British Museum, three presented this transition form. In one (Museum No. 2, c. 1130) the condition was particularly strongly marked. The torus supraorbitalis was divided into two distinct parts, the inner two-thirds, which contained the superciliary element, being very prominent as compared with the outer third.* This is to be looked upon as being merely the retention of a juvenile character. It is the rule in the young chimpanzee for the brow-ridges to begin to assume form at the time when the milk-teeth erupt. In the early stages it is generally possible to distinguish the superciliary element in the torus supraorbitalis; but, as a rule, after the second molar tooth has made its appearance the superciliary eminence becomes completely blended with the other elements which build up the torus, and the supraorbital projection assumes its typical form.

In the adult gorilla, the amalgamation of the different elements in the torus supraorbitalis is so complete that little indication of the composite character of the latter can be detected. Still, when the arch is viewed from above a general fulness in the superciliary region points to the presence of the superciliary element. I have not had the opportunity of studying the condition in the skull of the young gorilla.

The supraorbital region in the Neanderthal, Spy, and Krapina remains presents features which place it within Type III. As SCHWALBE has shown, the different elements have become blended in a strongly projecting torus supraorbitalis, in which there is little or no indication of its composite character. This undoubtedly forms one of the leading features of the race, but SCHWALBE is in error in concluding that the possession of an eyebrow region of this formation is the exclusive property of the Neanderthal group. Individuals are met with in recent races in whom the same formation may be seen in different degrees of development, and many specimens occur which present transition forms between Type II. and Type III.

In all large collections of Maori and New Guinea crania individual specimens which belong to Type III may be found; but in these cases the torus supraorbitalis, while showing a complete fusion of the superciliary and supraorbital elements and the formation of a continuous and uniform arch above the orbital opening, does not attain a great degree of projection, nor does it take much share in the formation of the orbital roof.

Amongst the Australian crania the case is different. Occasional specimens will be

* In another specimen (Museum No. 2A) the appearance presented by the supraorbital region strongly resembles the form usually seen in the aged baboon. A very evident groove (most evident on the left side) limits the superciliary element on its outer side.

found which present a torus supraorbitalis very similar to that present in the Neanderthal and Spy crania. The skull in the University collection which shows this character in the most pronounced form is figured in Pl. II., fig. 20. It is from a native of New South Wales (xxix. B. 1), and in general form and external configuration the eyebrow region exhibits a marked resemblance to the corresponding region in the Neanderthal cranium. A massive projecting bony arch, composed of the fused superciliary and supra-orbital elements, extends from the glabella to the fronto-malar suture.

Upon the right supraorbital torus of the Neanderthal cranium there is an oblique furrow which extends upwards and outwards for a distance of about 12 mm. (fig. 3, *s*). This groove is visible on the cast; and by both SCHAFFHAUSEN and VIRCHOW it was thought to be of traumatic origin. SCHWALBE, however, has shown that, although not continuous with, it yet lies in the line of a notch on the supraorbital margin, around which the supraorbital or outer branch of the frontal nerve had no doubt turned in its passage to the forehead (fig. 3, *k*). This naturally suggests the possibility that the groove in question is not the result of a wound, but is the pathway of the nerve. Against this conclusion must be reckoned the position and direction of the furrow. It courses over the outer third of the torus supraorbitalis, and its direction is so oblique that, if continued outwards, it would strike the temporal ridge about 14 mm. above the fronto-malar suture. It would seem unlikely, therefore, that the supraorbital nerve or one of its branches would pursue such an initial course on reaching the forehead. Still, it should be noted that in the Neanderthal cranium the supraorbital notch is situated much further out than usual. It interrupts the margin of the supraorbital arch much nearer its outer than its inner end (viz. 27 mm. from the fronto-malar suture, and 35 mm. from the fronto-maxillary suture). That this represents the notch in question there cannot be a doubt, because SCHWALBE has shown that on the roof of the orbit a distinct nerve-groove leads to it (fig. 6).

I have alluded to these features in the Neanderthal cranium because we find on the right side in the cranium of the New South Wales native (xxix. B. 1) a condition which in some respects is similar. The supraorbital notch cuts into the supraorbital margin about its mid-point, and from this two sharply defined grooves pursue a short divergent course on the under aspect of the torus supraorbitalis (figs. 20 and 21, Pl. II.). Immediately above the outer of these furrows and in a line with it is a shallow oblique sulcus on the front face of the torus. This recalls the groove on the right torus of the Neanderthal specimen; but its position is different. It does not lie so far out, and it is not so oblique in its direction.

I am inclined to think that in both the Neanderthal and New South Wales crania the groove in question is of the same nature, although I am satisfied that in neither case was it the pathway of a nerve. I believe that it represents in both cases the line of fusion between the superciliary and supraorbital elements of the torus. In the Australian skull, where the groove is faintly marked, and also in the Neanderthal cranium, where it is strongly marked, the condition resembles the appearance which is presented by the torus in those chimpanzee crania in which the superciliary element is not completely

blended with the supraorbital element. As has been already noted, a distinct groove is present in one of the British Museum specimens in this situation (Museum No. 2A).

On each side and at precisely the same place the supratrochlear nerve grooves the under aspect of the inner part of the torus supraorbitalis of the New South Wales cranium (Pl. II., figs. 20 and 21). In the Neanderthal cranium these nerves have been conducted to the forehead through two short canals which occupy precisely similar positions (fig. 6). It is interesting to note that, while the supratrochlear notches (when they exist) in the human skull show a great constancy in point of position, the supraorbital notches vary considerably in this respect.

In all questions relating to the district of the frontal bone under consideration the area immediately above the glabella and the eyebrow eminences is of high morphological import-

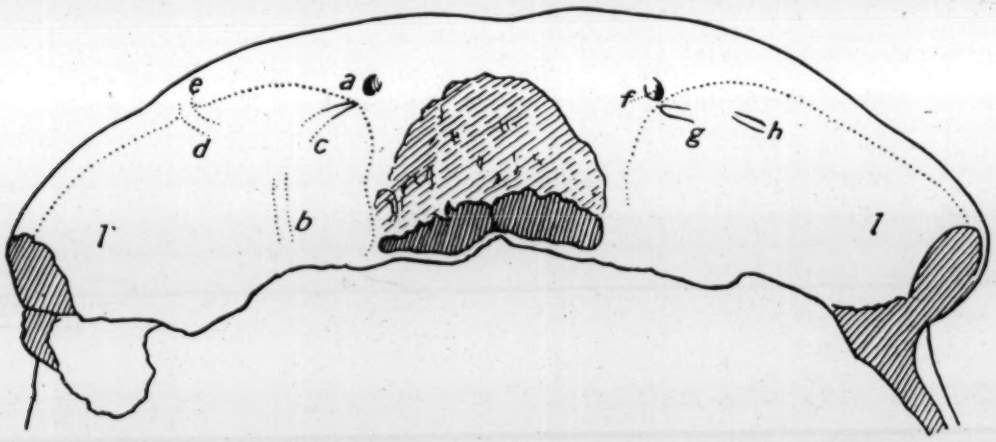


FIG. 6.—Orbital and nasal aspect of the Neanderthal cranium, from SCHWALBE ("Der Neanderthal Schädel," p. 38, fig. 10, 1).

*e*. Supraorbital notch.
*a*. Supratrochlear foramen.
*c*. Groove on roof of orbit for supratrochlear nerve.
*d*. Groove on roof of orbit for supraorbital nerve.
*b*. Groove on roof of orbit for frontal nerve.
*f*. Supratrochlear foramen.
*g*. Groove for supratrochlear nerve.
*h*. Groove for supraorbital nerve (?).
*l*. Lachrymal fossa.

ance. In this area SCHWALBE recognises three parts, viz. a median portion which he terms the facies supraglabellaris, and two lateral depressed portions which he calls the sulci supraciliares. The width and extent of the sulci supraciliares in the Neanderthal cranium constitute two of the most pithecoid characters in the Neanderthal and Spy crania. The massive eyebrow projection is separated from the curved frontal plate which covers the frontal extremity of the cerebrum by a wide depression which in some degree resembles the extensive depressed area which occupies a similar position in the adult chimpanzee and gorilla. This condition is associated with a low and flattened forehead, and bespeaks a feeble development of the frontal lobes of the cerebral hemispheres. As these lobes assume the massive rounded form distinctive of recent man, the cerebral part of the frontal bone assumes a higher degree of curvature for their proper accommodation, and its lower part advances towards the eyebrow region, and thus tends to diminish the

extent of the sulci supraciliares and also at the same time to tilt them forward, so that in the higher types of forehead their surfaces no longer look upwards as in the gorilla, but almost directly to the front. In this respect there cannot be a doubt that the Neanderthal cranium occupies an intermediate position between, say, the chimpanzee and the vast majority of recent skulls; but occasionally a recent skull is met with which shows an approximation to the Neanderthal condition, and which, so to speak, occupies the gap which exists in this respect between the Neanderthal race and man of the present day.

The New South Wales cranium is a specimen of this kind. It possesses tori supra-orbitales similar in form and constitution to those of the Neanderthal cranium, but it differs from the latter in the extent of the sulci supraciliares. These, it is true, have an unusual width and extent for recent man, being 10 mm. wide on the right side and 13 mm. wide on the left side; but they fall far short of the corresponding sulci in the Neanderthal cranium, which are 18 mm. wide on the right side and 19 mm. wide on the left side. Further, this broad sulcus in the Neanderthal cranium is more depressed, and its surface looks more directly upwards, than in the New South Wales specimen.

Associated with this approximation of the eyebrow region to the Neanderthal type, the New South Wales skull presents a low and degraded forehead. The bregma-nasion-inial angle is only 53°, and the index of the frontal curve is so low as 18 (3).

Amongst Australian crania it is possible to find specimens in which the eyebrow region conforms in every respect with the requirements of Type III., and yet possess, associated with this, a degree of frontal curvature as bold as that which is characteristic of the European skull. In Pl. II., fig. 22, there is reproduced the photograph of the skull of a male Queenslander. In this specimen the B.N.I. angle is no less than 64°—the average angle in the Australian being 60°, and in the Scottish 61°. Further, the index of the frontal curvature in the Queensland skull in question reaches the high figure of 24·5 (3). In this skull the eyebrow ridges form two continuous arches as in the Neanderthal cranium, but the supraciliary depressions are narrow grooves and look almost directly forward.

The two Australian skulls which I have selected as examples of Type III. of the supraorbital region exhibit this condition in a more marked degree than any other specimens in the ethnological collection of the University. In the twenty-five Australian skulls specially examined, Type III. occurred in three cases, all of which were males, viz. in two natives of Victoria and in one native of Queensland. I have not seen this type of supraorbital region in any female skull.

Amongst the Australians, transitional forms of the eyebrow region between Type II. and Type III. are very common. One of the most remarkable instances of this is to be seen in the skull from the Riverina district to which reference has already been made (xxix. B. 12). In this specimen the eyebrow eminences are very pronounced (Pl. III., fig. 24). As mentioned before, the glabellar part of the frontal bone measures over the curvature 41 mm., or only 2 mm. less than the correspond-

ing part of the Neanderthal cranium. The eyebrow projections form an almost continuous arch from the glabella to the extremity of the external angular process of the frontal bone; still, the line of fusion between the superciliary and supraorbital elements is clearly indicated by a faint groove. There is no trigonum supraorbitale. A specimen such as this is very instructive, because it shows that the arched eyebrow elevation (the torus supraorbitalis) distinctive of Type III. is not merely formed by a strengthening of the superciliary eminence and by its fusion with the supraorbital part, but also by a great development of the latter as well. These changes lead to an obliteration of the trigonum supraorbitale—the feature which SCHWALBE considers distinctive of all recent skulls. This increased development of the supraorbital element is also evident in the baboon, although the projecting arch-like elevation which it forms is sharply cut off from the superciliary eminence by a pronounced sulcus. The study of the ape skull as well as a large series of human crania thus renders evident the steps by which the three different types of the supraorbital region have been evolved, and more especially do we see the manner in which Type II., which is chiefly characteristic of recent man, may be transformed into Type III., which is distinctive of the gorilla, the chimpanzee, the Neanderthal race, and also of a few exceptional individuals of the present day.

### SUPRAORBITAL REGION IN THE ORANG AND THE GIBBON.

Had our survey been extended over the entire range of the order Primates, it would have been necessary to have recognised other types besides the three which we have stated include all human skulls and the majority of ape skulls. The condition in the orang, for example, is interesting in so far that there is no evidence of the presence of a superciliary element. The supraorbital elements gradually develop into a projecting rim for the upper part of the orbital opening. In the young skull this makes its appearance about the same time as the milk-teeth. At first it is very feebly expressed and separated from the cerebral part of the frontal bone by a narrow groove. Towards the glabella it is extremely narrow, but as it is traced outwards it broadens, and as age advances it becomes more and more projecting and rough, until ultimately in the adult its outer part occupies the whole field of the trigonum supraorbitale. It presents the appearance at this stage as if it were something superadded to the frontal bone, and might be compared to the upper segment of an oval frame attached to the frontal portion of the margin of the orbital opening. Inasmuch as it does not contain a superciliary element, it is not a true torus supraorbitalis, and further, it does not take a large share in the formation of the roof of the orbit.

In certain aged specimens of the orang skull the narrow inner end of this supraorbital projection may be seen to expand in the glabellar region into a rounded knob-like eminence. Such cases are not common, and they suggest the possibility of this expansion being the representative of a superciliary eminence. I do not think, however, that it can be reckoned as such.

There are some forms of gibbon in which it is impossible to detect a superciliary

element, and in which the supraorbital region presents a close resemblance to the condition present in the orang. In most cases, however, there is a strong tendency exhibited for the inner end of the supraorbital arch to swell out into a bulbous extremity at the glabella. This in all probability is the superciliary element; indeed, it may sometimes be seen to partially disengage itself from the supraorbital arch and present a condition which may be classed under Type II.

### Relation of the Supraorbital Region to the Orbit.

Schwalbe rightly lays stress upon the fact that in the majority of apes the supra-

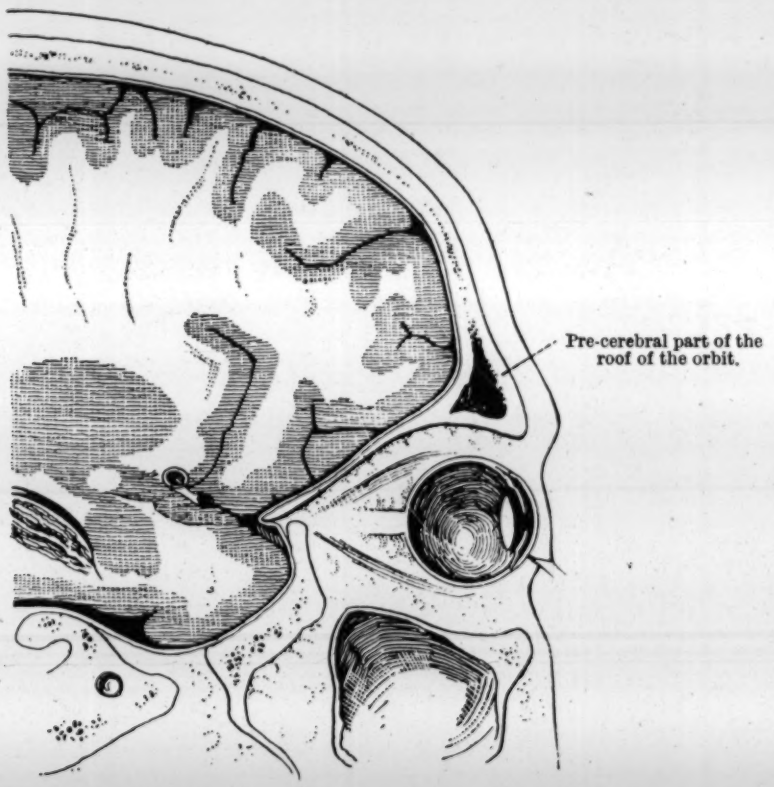


Fig. 7.—Tracing from a sagittal section through a frozen male head (Irish), in a plane corresponding to the mid-point of the supraorbital arch (reduced).

orbital eminence, which juts forward in a shelf-like manner from the front of the true brain-capsule, forms a considerable part of the roof of the orbit. The degree of prominence to which this condition may attain varies in different groups, and may be demonstrated by making a sagittal section through the frozen head in a plane which passes through the mid-point of the supraorbital arch. This method has the further advantage of showing the relation which this pre-cerebral part of the roof of the orbit presents to the eyeball.

In the adult male gorilla the torus supraorbitalis may form as much as the anterior half of the orbital roof, and a similar relationship may also be seen in a pronounced form in the chimpanzee, baboon, and other forms of ape. This character is strictly correlated with the extent of the area to which we have applied Schwalbe's term of

sulcus supraciliaris. As the brain advances in its phylogenetic growth, it reduces the width of this sulcus, encroaches upon the eyebrow projection, and extends the area of the orbital plate of the frontal bone which intervenes between the cerebrum and the orbital cavity.

At the same time it should be noted that even in the European a considerable part of the orbital roof may be formed by the supraorbital projection of the frontal bone. In fig. 7 is shown a sagittal section through the head of an Irish subject in which the eyebrow region was somewhat prominent. It will be seen that very nearly one-third of the orbital roof is formed by the under surface of this part of the frontal bone. Further, it will be noted that three-fourths of the eyeball lie in front of the brain and under shelter of this portion of the bone.

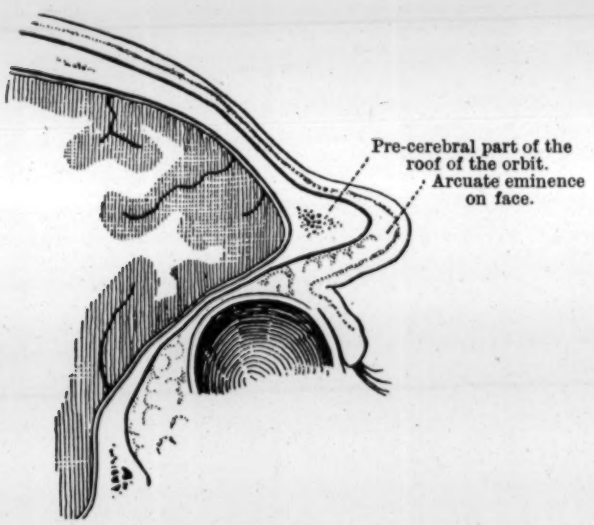


FIG. 8.—Sagittal section through the frozen head of a young male chimpanzee, in a plane to the outer side of the mid-point of the supraorbital arch.

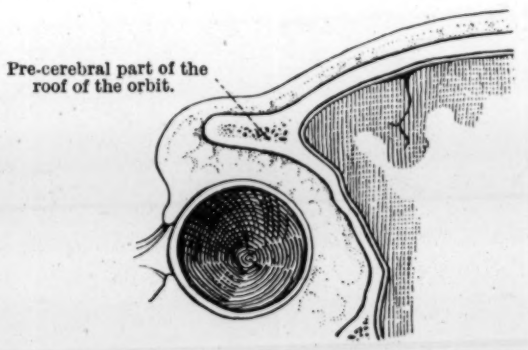


FIG. 9.—Sagittal section through the frozen head of an adult gibbon (*Hylobates agilis*) in a plane corresponding to the mid-point of the supraorbital arch. Note the large share which the torus supraorbitalis takes in the formation of the roof of the orbit.

Those familiar with the facial aspect of the gorilla and chimpanzee know that the torus supraorbitalis is not only concerned in forming a large part of the wall of the orbit, but also in producing a strong arch-like projection which juts forward on the face above and in front of the eyeball. Fig. 8 was obtained from a tracing of a sagittal section of a young chimpanzee (probably about three or four years old); the torus is thus far from having attained its full degree of development. Still, the manner in which it forms the facial feature referred to is manifest. In one respect this section cannot be compared with the other sections shown in figs. 7 and 9. The impression which it gives of the relation presented by the roof of the orbit and the brain to the eyeball is somewhat misleading. It will be noticed that the section has been made through a different plane. Had it passed through the same plane as in the case of the human head, the relation presented by the eyeball to the roof of the orbit and the brain would not have been markedly different from what we

see in the other figures (see fig. 1, Pl. X., *Cunningham Memoir* No. 2, Royal Irish Academy, 1886).

Instructive tracings of the frontal bone, which show in some measure the relation of the torus supraorbitalis to the roof of the orbit, are given by SCHWALBE for the Neanderthal cranium and by SOLLAS for the Gibraltar cranium. In these the outline of the posterior surface of the bone is not represented, and thus it is not possible to estimate the precise extent of orbital wall which is formed by the torus. Still, by these tracings, and also by an examination of the cast of the Neanderthal cranium, it is evident that in this respect the Neanderthal race presents a very marked approach to the pithecoid type. On this point I am in complete agreement with SCHWALBE. In no recent human cranium is the orbital roof so largely formed by the supraorbital projection of the frontal bone.

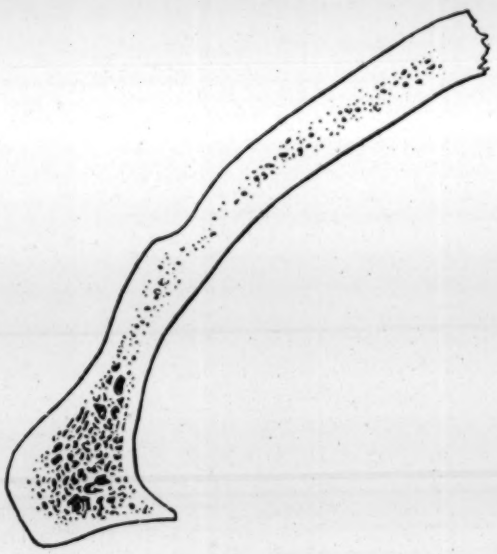

FIG. 10.—Sagittal section through the mid-point of the supraorbital arch of the New South Wales cranium (xxix. B. 1).

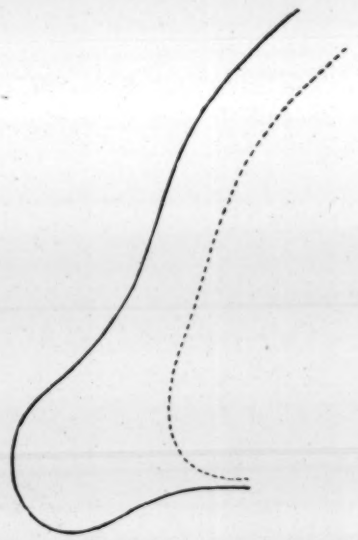

FIG. 11.—Tracing of the frontal bone of the Neanderthal cranium at the mid-point of the supraorbital arch. (From SCHWALBE, "Zur Frage der Abstammung des Menschen," fig. 4, p. 22.)

Nevertheless, specimens are met with which present some similarity to the Neanderthal cranium in this character. The New South Wales cranium (xxix. B. 1) to which we have so frequently referred is a case in point. A section through the frontal bone of this specimen in a sagittal plane corresponding to the mid-point of the torus supraorbitalis is shown in fig. 10, and when this is compared with SCHWALBE'S tracing of the same region in the Neanderthal cranium (fig. 11) a decided resemblance is apparent. To SCHWALBE'S tracing I have added by a dotted line what may be regarded as indicating the approximate position of the posterior surface of the frontal bone, or in other words the outline of the cerebrum. If this has been accurately represented (and I think that, when it is contrasted with the drawing of the New South Wales specimen, it will be admitted that it cannot be very far wrong), the maximum length of the pre-cerebral part of the roof of the orbit in the Neanderthal is 20 mm., and in the New South Wales cranium 16 mm.

## Relation of the Superciliary Eminence to the Frontal Air-Sinus.

That the degree of prominence of the glabellar and supraorbital regions of the human skull is not necessarily determined by the degree of development of the frontal air-sinus is proved by the writings of Bianchi (1), Zuckerkandl (15), Logan Turner (14), and Schwalbe (6, 8, 10). Further, the topographical independence of the area represented by the air-sinus and that occupied by the superciliary eminence is a well-established fact. Two questions, however, of much difficulty remain to be considered: (1) Can any morphological connection be established between the superciliary eminence and the frontal air-sinus? and (2) if no such relationship exists between these two factors, what is the morphological significance of the superciliary eminence, and how can its presence in so large a number of the members of the primate group be explained?

In considering these problems it should first be noted that where the superciliary eminence fails the air-sinus is also usually absent. We may take the orang as an example of this. As we have noted, there is apparently no morphological equivalent of the superciliary eminence in the orang. It is not correct to say, however, that in this animal the frontal air-sinus is never developed. In the British Museum I had the opportunity of making a tracing of the bisected skull of an adult orang in which a small sinus was present.

But the absence of the sinus in cases in which there is no superciliary eminence proves very little. On the other hand, we are confronted with the fact that there are numerous catarrhine apes in which the superciliary eminence is highly developed, and yet in which there is not a trace of the sinus. Further, it should be borne in mind that, as Dr Logan Turner has so clearly demonstrated, the sinuses are not infrequently absent in individuals of apparently all races of man. According to this authority, they are absent in 7·5 per cent. of European skulls.

It would almost appear, therefore, that there is no morphological connection between the superciliary eminence and the frontal air-sinus, and yet when we make a vertical section through the region in one of the lower apes (as, for example, the baboon or the macaque) we see that the eminence is due to a separation of the two tables of the frontal bone and the replacement, between them, of the ordinary diploe by open cancellous tissue. Indeed, the condition is identical to the changes which occur in the young human frontal bone preparatory to the extension into the region of the nasal cavity to form the frontal air-sinus (fig. 12). No doubt this is suggestive, but I am afraid we cannot conclude from this fact alone that any clear connection exists between the condition present in these apes and the subsequent step which leads to the formation of an open air-sinus in certain of the anthropoids and man. Still, it is just possible that the condition may indicate in these apes the phylogenetic step by which the sinus formation has been reached.

If, then, as seems likely, there is no morphological connection to be traced between the superciliary eminence and the frontal air-sinus, how can we account for the presence of the former? It is not required for the formation of an efficient torus supraorbitalis;

this can be formed without its aid. As we have seen, the superciliary eminence frequently appears as an isolated eminence, standing absolutely independent of, and apart from, the other elements of the region. I suspect that this problem must remain, for the meantime at least, unsolved. It may be that, by adding to the volume of the supraorbital projection, the superciliary eminence increased the aspect of ferocity, which is generally associated with projecting brows, and thus contributed to the face a feature which would no doubt have been a decided advantage in those early struggling days. Little gain, however, is to be acquired by following a line of thought so highly speculative.

As is well known, the torus supraorbitalis in the gorilla and the chimpanzee is chiefly composed of dense bone. The frontal air-sinuses are relatively small, and are

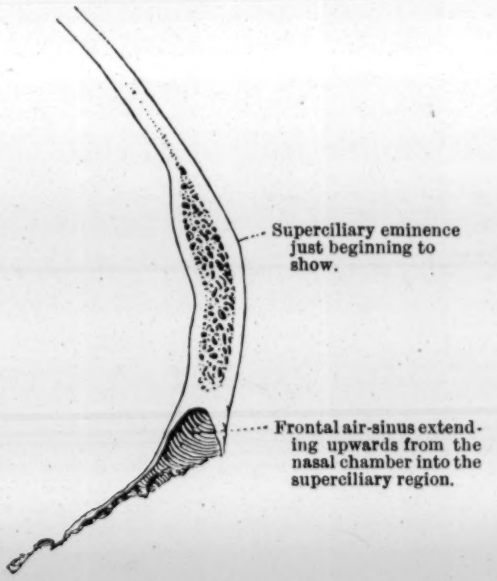


FIG. 12.—Sagittal section through the frontal bone of a child, in the region of the superciliary eminence.

situated at the base of the torus, close up against the inner table of the cranial wall. Further, they are chiefly confined to the glabellar region, and do not extend for any distance outwards into the superciliary part of the torus. Much interest is therefore attached to the observation of Professor SCHWALBE (8) that in the Neanderthal cranium the air-sinuses lie well back, and that a thick layer of condensed bone forms their anterior wall. It is usual to find a similar pithecoid condition in the supraorbital region of the native Australian. The frontal air-sinuses, in this race, are as a rule relatively small, and they lie behind a mass of condensed bone. Thus Dr LOGAN TURNER (14) was only able to map out these sinuses by the illumination method in less than a third of the Australian skulls he examined (in 20 out of 69 skulls), and in a very large number (30·4 per cent.) he found both sinuses totally absent. Amongst the Maori skulls, which, as we have noted, also show a tendency to Type III. of the eyebrow region, the same observer states that both sinuses were absent in 37 per cent. of the specimens he examined. These are striking facts, and undoubtedly point to an important affinity in this

respect between the native Australians and the Neanderthal race on the one hand, and of both of these to the chimpanzee and the gorilla on the other hand.

### The Supraorbital Notch and its Relation to the Eyebrow Eminence.

Schwalbe has pointed out that the supraorbital notch bears an important relation to the eyebrow eminence. A glance at figs. 17, 18, and 19, Pl. I., which exhibit the region in the baboon, shows that this notch is the starting-point on the margin of the orbital opening from which the oblique groove, which intervenes between the superciliary and supraorbital elements, proceeds. Even in Type III. of this region, where the different elements are massed together with no external indication of their separate identity, Schwalbe takes the supraorbital notch as giving the only clue to the demarkation of the superciliary and supraorbital elements of the eyebrow projection. Schwalbe has failed to appreciate, however, that the supraorbital notches in man and the lower apes are not morphologically equivalent, nor yet similarly placed on the margin of the orbital opening. In other words, the disposition of the frontal nerve in man and the ape is different.

In man the frontal branch of the ophthalmic division of the trigeminal nerve pursues a straight course within the orbit upon the upper surface of the levator palpebræ superioris, and about midway between the inner and outer walls of the cavity. At a variable point it gives off its supratrochlear branch and is continued onwards as the supraorbital nerve. The supratrochlear nerve inclines inwards towards the inner wall of the orbit, and finally turns round the inner part of the orbital margin above the trochlea of the superior oblique muscle to gain the forehead. As a rule it leaves no mark upon the bone as it winds on to the forehead; sometimes, however, its path is indicated by a groove, as in the New South Wales cranium (figs. 20 and 21, Pl. II.), and at other times it may pass through a foramen, as in the case of the Neanderthal cranium (fig. 3, p. 288, and fig. 6, p. 298). These markings are more frequently present in the crania of lower races, and more especially in those with a projecting glabellar and eyebrow region.

The supraorbital nerve, or the continuation of the frontal trunk, reaches the forehead by turning upwards in the supraorbital notch or foramen. This notch is variable in position, but usually it lies a little to the inner side of the mid-point of the supraorbital margin.

Mr Ninian Bruce, B.Sc., has kindly made dissections for me of the orbital cavity in three chimpanzees, one orang, one yellow baboon, and in several species of the genus Macacus. These have shown that the frontal nerve in the ape does not present the same relations within the orbital cavity as is the case in man.

In the baboon and the macaque the frontal nerve does not divide into two branches within the orbit, but issues from that cavity in the form of one undivided trunk. Further, this nerve courses through the orbit in close relationship to its inner wall, and

turns round a wide and conspicuous notch on the inner part of the supraorbital margin and immediately to the outer side of the glabella (fig. 19, Pl. I.). It follows from this that the supratrochlear nerve in man is the representative of the whole nerve in the baboon and macaque, and that the occasional groove or foramen on the orbital margin associated with it is the morphological equivalent of the large single notch in the lower ape. The new position of the frontal nerve in man (on the upper surface of the levator palpebræ superioris and midway between the outer and inner walls of the orbit) and the passage of the greater number of its fibres through a new nerve (the supraorbital) is a condition which has probably been brought about by the increase in the breadth of the human forehead, which renders it necessary for the greater number of the group of nerve-fibres which go to supply the skin of this area to be shifted in an outward direction. Like most acquisitions of recent phylogenetic origin, the condition is one which is liable to considerable variation. Not only is the relative size of the two branches of the frontal nerve in man subject to variation, but also the position of the supraorbital notch on the orbital margin is very far from being constant.

The arrangement of the frontal nerve in the orbit of the chimpanzee and orang is slightly different from that which was seen in the baboon and macaque. The nerve still clings to the inner wall of the orbit, but when it comes to the region above the trochlea it divides into two branches, which no doubt correspond to the supratrochlear and supraorbital branches in man. This division takes place below the front part of the torus, and the supratrochlear is carried onwards in an upward and inward direction around the inner part of the supraorbital arch and immediately to the outer side of the glabella. The outer branch or the supraorbital nerve turns sharply outwards on the under surface of the torus, and then winds on to the forehead in an oblique and often very obscure groove, which is the representative of the supraorbital notch in man.

This arrangement of the nerve can usually be made out in a very distinct manner in the skull of the adult gorilla. From the markings on the bone it becomes evident that the main portion of the nerve turns over the torus close to the inner wall of the orbit in a very shallow groove which partakes more of the nature of a smooth pathway. This lies above and in front of the trochlear pit.

In nine out of eleven gorilla skulls there was evidence that the frontal nerve had divided close to the margin of the orbital opening, and further, that the outer branch (*i.e.* supraorbital) had diverged from the inner branch almost at a right angle before turning round the supraorbital margin. The two shallow pathways for these nerves are distinctly marked on the bone, and in a large male skull they were separated at the points at which they turned upwards by an interval of 10 mm. As a rule they are separated from each other by a low spine-like projection upon the under surface of the torus.

In no sense either in the chimpanzee or the gorilla can either of these grooves be taken as giving an indication of the line of fusion between the superciliary and supra-orbital elements of the torus supraorbitalis. This can be seen in those young specimens

of chimpanzee skulls to which we have referred as showing in more or less distinct outline the superciliary element as a part of the torus.

The foregoing facts are important in connection with SCHWALBE's views in regard to the supraorbital notch, and they are also of high interest when we apply them to the information we possess regarding the eyebrow region in the Neanderthal cranium.

SCHWALBE has given us a most careful account of the orbital roof and supraorbital margin in the Neanderthal cranium (8), and has supplemented his description by an instructive outline drawing (fig. 6, p. 298) and a photograph (fig. 7, Pl. I.) of the under surface of the frontal bone. From these it is apparent that to a large extent the human arrangement of the frontal nerve has been present in the Neanderthal race. The division of the nerve-trunk is clearly indicated by groovings on the orbital roof, and the presence of a foramen for the supratrochlear part and a notch for the supra-

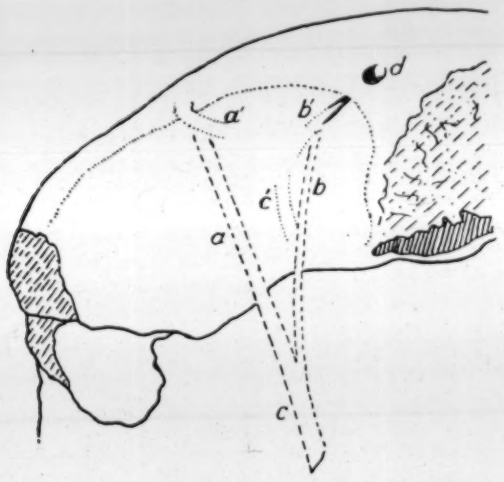


FIG. 13.—Diagram to show position of frontal nerve and its branches in the Neanderthal specimen and in recent man.

*a*. Supraorbital nerve (recent man).
*a'*, *b'*, *c'*. Markings on roof of orbit of Neanderthal cranium.
*b*. Supratrochlear nerve (recent man).
*c*. Frontal nerve (recent man).
*d*. Supratrochlear foramen.

orbital part are clearly delineated—more especially on the right side. But whilst this is the case, certain pithecoid characters are evident: (1) the groove on the orbital roof which conveyed the frontal nerve lies nearer to the inner wall than we are in the habit of seeing it in recent man; (2) the two branches of the nerve diverge widely and abruptly from each other like the limbs of the letter Y, and of the two the supratrochlear branch seems to lie more in the line of the parent trunk than the supraorbital; (3) the groove and the foramen for the supratrochlear branch show that this nerve must have been unusually large, *i.e.* judged from the human standpoint. These features bespeak a nearer approach to the ape; but in making this statement we must not lose sight of the fact that in several Australian crania in the Museum of the University there are markings which also point to pithecoid leanings of a somewhat similar nature.

But the interest in the nerve-markings is not exhausted by a study of the supra-

trochlear and supraorbital grooves, notches, and occasional foramina. Anyone who makes a comparative study of the region will be naturally led to inquire, in the case of Type II., whether the sulcus which separates the superciliary and the supraorbital elements is not in great part produced by the supraorbital nerve in the first part of its course on the forehead. When I began my investigation this view appealed strongly to me, and gained force from a dissection which I made of a young yellow baboon, in which the nerve undoubtedly occupied the whole length of the sulcus in question. Subsequent research, however, has shown that, while the nerve may turn outwards in the groove for a short distance, the sulcus cannot in any sense be regarded as a nerve pathway.

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Having now taken a general survey of the morphological characters of the eyebrow eminences in man and the apes, we are in a position to discuss the view expressed by Professor SCHWALBE that these features alone are sufficient to constitute a specific difference between the Neanderthal race and all other races of mankind. In coming to this conclusion, it seems to us that SCHWALBE in some degree exaggerates the importance of the features in question, and has failed to take into account the numerous individual crania of recent races which are found to some extent filling up the gap which exists in this respect between the Neanderthal cranium and the crania typical of the races of the present day.

The leading peculiarities of the Neanderthal eyebrow region are :—

1. Its striking degree of prominence.
2. Its external configuration and its morphological constitution.
3. Its relation to the cerebral part of the frontal bone and to the roof of the orbit.

In so far as 1 and 2 are concerned, the Neanderthal cranium may be said to fall within the limits of the races which exist at the present day. As we have seen, individual crania are found amongst the Australians which exhibit very nearly, if not quite, as great a prominence in the glabellar region. Nor are the general configuration and the constitution of the eyebrow projection which are characteristic of the Neanderthal group peculiarities which belong to this race alone. In these respects they are associated in Type III. with many individuals of other existing races.

As SCHWALBE has recognised, it is in the relation of the supraorbital projection to the cerebral and the orbital cavities that the most important distinction lies. But even in this respect we find in recent man transition forms, and we have indicated the New South Wales cranium as a case in point. Further, it has long been known that in the Australian, notwithstanding the projection of the eyebrow region, the tendency is towards the formation of frontal air-sinuses of small size. In the Australian skull, as in the Neanderthal cranium, the eyebrow eminence is as a rule largely formed by a massing of the bone in front of the air-chamber.

It is doubtful if much profit can be derived from a discussion as to whether the

eyebrow characters in the Neanderthal cranium are to be accorded a specific value or not. A question of this kind is decided on more or less conventional grounds, and must be answered by each one for himself according to the interpretation which he puts upon the word "specific." At the same time it must be admitted that if we examine the basis on which zoological classification rests we shall find many cases in which species are determined upon evidence more slender than that which SCHWALBE brings forward in favour of establishing the species of *Homo primigenius* for the reception of the Neanderthal people.

There cannot be a doubt that the formation of such a species would be convenient in many ways; but even allowing for the vague and indefinite understanding which exists amongst biologists regarding the determination of what characters should be elevated to the plane of specific importance and what characters should not, I can hardly bring myself to believe that we would be justified in adopting this course from the characters presented by the supraorbital region in the Neanderthal race.

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## EXPLANATION OF PLATES.

### Plate I.

Fig. 14. Skull of a young *Macacus cyclops*. The superciliary eminences are seen in the form of two isolated, oval, slightly raised areas. (Type I.)

Fig. 15. Skull of *Macacus rhesus*. Superciliary eminence strongly marked, elongated, and separated from the supraorbital margin in its whole length. (Type I.)

Fig. 16. Skull of adult chimpanzee (Goodsir series). Torus supraorbitalis well marked, but it will be noticed that the superciliary eminence has not been completely absorbed into it. The general outline of the superciliary eminence is distinct, and it also presents a distinctive texture. (Type II. merging into Type III.)

Fig. 17. Skull of a young chacma baboon (*Cynocephalus porcarius*, Turner series). The superciliary eminences stand clear of the supraorbital margin. (Type I.)

Fig. 18. Skull of an adult baboon (species doubtful). The superciliary eminences by their inner parts are confluent with the inner parts of the supraorbital margins. (Type II.)

Fig. 19. Skull of an adult Anubis baboon (*Cynocephalus anubis*). Shows a nearer approach to the fusion of the superciliary and supraorbital elements of the region than in fig. 18.

### Plate II.

Fig. 20. New South Wales cranium (xxix. B. 1, Turner series). Tori supraorbitales well marked. (Type III.) *a*, supratrochlear grooves; *b*, supraorbital notches.

Fig. 21. New South Wales cranium (xxix. B. 1). Orbital aspect of the frontal bone. *a*, supratrochlear grooves; *b*, supraorbital notches. Note how the interorbital region is pinched in between the two supratrochlear nerves.

Fig. 22. Australian skull from the Queensland district (xxix. A. 10, Turner series). Tori supraorbitales with a steep and highly curved forehead. (Type III.)

### Plate III.

Fig. 23. Skull of a native of New Hebrides Islands (xxvii. C. 3, Turner series). Type II. of the supraorbital region. Contrast with fig. 18, Pl. I.

Fig. 24. Skull of native of Australia from Riverina district (xxix. B. 12, Turner series). Very projecting supraorbital region; transition condition between Type II. and Type III.

Professor D. J. CUNNINGHAM on "The Evolution of the Eyebrow Region of the Forehead."—PLATE I.

FIG. 14.

FIG. 17.

FIG. 15.

FIG. 16.

FIG. 18.

FIG. 19.

Professor D. J. Cunningham on "The Evolution of the Eyebrow Region of the Forehead."—Plate II.

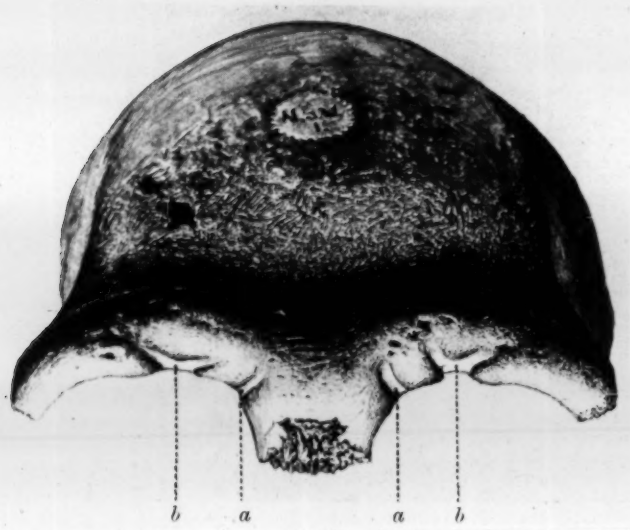


Fig. 20.

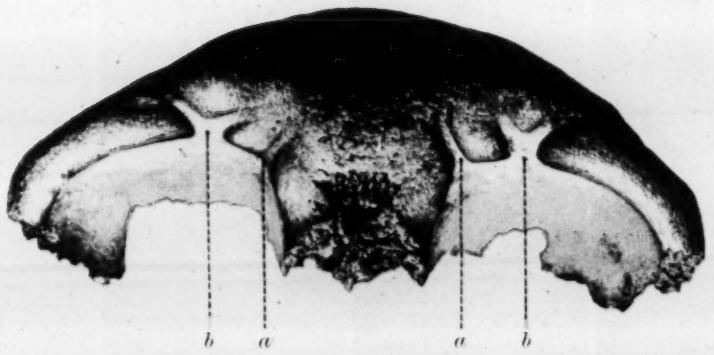


Fig. 21.

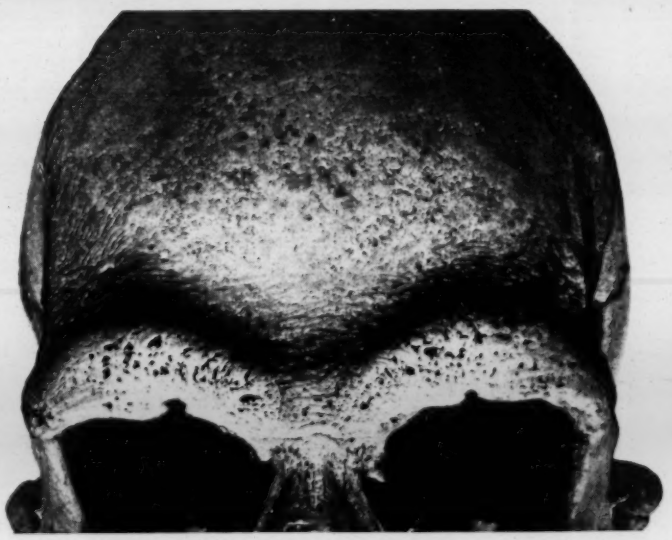

Fig. 22.

Professor D. J. Cunningham on "The Evolution of the Eyebrow Region of the Forehead."—Plate III.

Fig. 23.

Fig. 24.

# XIII.—On the Age of the Old Red Sandstone of Shetland. By John S. Flett, M.A., D.Sc.

(Read March 18, 1901. MS. received May 26, 1908. Issued separately July 8, 1908.)

In spite of its remote situation, the Old Red Sandstone of Shetland attracted a considerable amount of attention from geologists during the last century. It is exposed in excellent coast sections, which often yield very beautiful cliff scenery; and, in addition to being the most northerly of the stratified rocks of Great Britain, it includes a rich succession of volcanic and intrusive rocks which are of great interest and variety. The axis or backbone of the Shetland archipelago consists of gneiss, mica schist, slate, and limestone, with epidiorites, serpentine, and talc schists. On each side of this there is an area of Old Red Sandstone; that on the east extending from Sumburgh Head, in the extreme south, to Rovey Head, a little north of Lerwick, and comprising also the islands of Bressay, Noss, and Mousa. On the west side of Shetland the Old Red Sandstone Series is much altered, probably by the heat of the granite and other intrusive rocks, so that they often have the appearance of quartzite, and were for a long time regarded as belonging to the metamorphic series. In 1879, however, Peach and Horne (28) showed that, in places, they contained fossil plants which indicated that they belonged to the Old Red Sandstone formation.

The earliest accounts of the Old Red rocks of Shetland are to be found in the descriptive works of Jameson (16), Neill (25), Boué (1), Shireff (34), Fleming (2), and Hibbert (14). These writers were all of the Wernerian school, and described the conglomerates, sandstones, and flags as "secondary," resting on the "primitive" or metamorphic group. Of these accounts the best are those of Hibbert and of Fleming; the latter in particular deserves mention, as being the first to record the occurrence of fossil plants in the Lerwick Sandstones.

In 1853 an important advance was made by the description of some fossil plants from South Ness, Lerwick, by Dr (afterwards Sir) Joseph D. Hooker (15). He referred them to two species of Calamites. This paper was communicated to the Geological Society of London, and was accompanied by a note by Sir Roderick Murchison (21), in which he stated his conviction that "the sandstone of Lerwick is of the same age as the rocks of Elgin, Burghead, Tarbet Ness in Ross, and Dunnet Head in Caithness, all of which Professor Sedgwick and myself described as constituting the uppermost member of the Old Red Sandstone, and as overlying the Caithness flagstones, with their numerous ichthyolites."

Murchison, accompanied by Sedgwick, had already visited Caithness, Ross, and Cromarty, and was familiar with the Old Red Sandstone of these districts (33). He subsequently proceeded again to Caithness, and thence to Orkney and Shetland (5). The

impressions he received on this visit confirmed the opinion he had already formed, and led him to place these beds definitely in the younger portion of the Old Red Sandstone (22), (23).

The subdivision of the Old Red Sandstone of Scotland into Lower, Middle, and Upper, which Sir R. MURCHISON had advocated, was discarded by Sir ARCHIBALD GEIKIE (6) in his well-known paper on the Old Red Sandstone of Western Europe (Part I.), which still forms the principal source of information regarding the Orcadian Old Red Sandstone. He proved definitely that the Upper rested in Hoy and elsewhere, with a marked unconformability, upon an eroded surface of the Orcadian (7); but the Middle and Lower subdivisions of MURCHISON he grouped into one. The evidence of the fossil fishes and fossil plants points to their being distinct formations; and in its recent Memoirs (19) the Geological Survey of Scotland has reverted to the threefold grouping of MURCHISON.

In his paper, Sir A. GEIKIE does not express any decided opinion as regards the exact horizon of the Shetland Old Red. He recognises that MURCHISON had relied mainly on HOOKER's determination of the Lerwick plants as Calamites in assigning these beds to the topmost portion of the system; and as this identification had been shown to be dubious (32), the conclusion arrived at was hardly valid. The great resemblance of the volcanic rocks in this series in Shetland to those in the Caledonian (Lower) Old Red of Scotland, and the occurrence in Shetland of *Estheria membranacea*, known also in the flagstones of Caithness and Orkney, were pointed out, and no doubt led him in subsequent years to include the Shetland beds with his Lower Old Red Sandstone. At any rate, this is the correlation that was ultimately accepted by him (8), (9).

About the same time as Sir ARCHIBALD GEIKIE's paper appeared, Professor HEDDLE published his geognosy of Shetland (13), in which brief space is given to the Old Red Sandstone. In Dr GIBSON's account of the Old Red Sandstone of the East of Shetland (12) very careful descriptions of the lithology of the beds are given, but the lack of fossil fishes is deplored. In the absence of more definite evidence, it is assumed that the horizon of these beds is the same as that of the Caithness flags.

In 1879 the first of a series of papers on the geology of Shetland by Dr PEACH and Dr HORNE appeared in the *Quarterly Journal* of the Geological Society of London (28). This included a description of the Old Red Sandstone, and was followed by two others. The remarkable series of volcanic rocks was specially investigated (29). It is not too much to say that, as the result of their work, amplifying and correcting the earlier descriptions of HIBBERT, HEDDLE, GEIKIE, and GIBSON, the geology of Shetland, varied and complex though it is, is better known than that of any part of Scotland which has not been mapped by the Geological Survey. Four excellent maps of the geology of Shetland have been published, one by Professor HEDDLE (13) and three by Dr PEACH and Dr HORNE (28), (29), (30).

To their accounts of stratigraphy of the Old Red Sandstone of Shetland, and its relations to the older metamorphic rocks, little remained to be added. As regards the age of these beds they maintained a conservative attitude, though acquiescing in Sir

A. Geikie's relegation of them to the Lower division of the system (which, of course, included the Orcadian). In this opinion they were supported by C. W. Peach (27), who re-examined the fossil plants described by Hooker, and found that they exhibited close affinities to those obtained in the Old Red of Caithness and Orkney.

In 1898, after spending part of several years in investigating the Old Red Sandstone of Orkney (3), I determined to visit Shetland and make a search for fossil fishes which would establish the position of the sandstones and shales of these islands relatively to those of Caithness and Orkney. Six weeks were spent in a scrutiny of all the best exposures on the east side of the mainland from Sumburgh Head to Lerwick, and in the islands of Bressay and Noss. The results, though unsatisfactory, were not entirely disappointing, as indecipherable fragments of fishes were obtained in Bressay, at Lerwick, Sandwick, and the east side of Quendale Bay. Further search was determined on; and to meet the expenses of quarrying, a grant was applied for from the Royal Society of London (Government Grant Committee), which was conceded. Consequently, in 1899, with the consent of the late Mr Hamilton, of Unst, an opening was made in the beach on the east side of Cullingsburgh Voe in Bressay, and our expectations were soon confirmed by the discovery of scattered plates of undoubted fossil fishes belonging to new species. These fishes were handed to Dr Traquair for identification, and a preliminary notice was inserted in *Nature* to announce the discovery of a new zone of the Old Red Sandstone of Scotland (24).

## The Fish-bearing Beds of Bressay, and their Position in the Old Red Sandstone of Shetland.

As recognised by all who have described this area, the structure of the district around Lerwick and Bressay is exceedingly simple. A little west of Lerwick, coarse conglomerates are faulted against the metamorphic series. They dip towards the east, and are succeeded at the town of Lerwick by reddish and grey sandstones, often current-bedded, and sometimes containing large rounded pebbles of quartzite, granite, etc. At the point south-east of Lerwick known as the Nabb, grey micaceous sandstones occur, full of plant-remains, and containing also the small crustacean *Estheria membrancea* (22). On the opposite shore of Bressay Island the first beds met with are brownish and grey sandstones, often conglomeratic, and sometimes brecciform, with occasional grey and reddish shales. A series of faults or crush belts run nearly north and south along this side of the island from Maryfield to Ham, setting the beds frequently on end, and converting them into breccias and crush conglomerates. In crossing Bressay the dip of the rocks is consistently east or south-east, varying from ten to thirty degrees. The commonest rocks are grey, micaceous, thin-bedded sandstones, with coarser, less micaceous, gritty seams, often current-bedded. The sandstones contain rounded clay galls, and their surfaces are often covered with blackened fragments of plants and shreds of fine shale. Small faults are frequently seen in the coast sections, mostly running parallel to the strike. On

the west side of Noss Sound a small volcanic neck, described by PEACH and HORNE (29), occurs, with a thin bed of ash. Faulting also is visible here, and the beds are often steeply inclined. In Noss the easterly dip again prevails, and in the great cliff on the east side of this island a fine section of thin flaggy sandstone and grey shales is exposed, exceedingly well stratified, and resembling closely many of the cliff features of Orkney and Caithness.

In view of the persistent easterly dip, often at fairly high angles, the whole thickness of this series must be several thousand feet; but the evidence of faulting along the shores of the Sounds is sufficient to render exact estimates impossible. The fish beds in Cullingsburgh Voe are rather above the middle of the Bressay Sandstones. The fossils occur in a thin-bedded, flaggy, grey micaceous sandstone, and the plates are black in colour and well preserved. With them thin black impressions of plants are exceedingly common. The strata were evidently laid down in shallow water, close to land; and the general facies of the rocks and of the fauna is in harmony with the supposition that they were fresh-water deposits.

Fossiliferous bands must occur in Bressay besides that in which our excavations were made, as we found a fish fragment in a beach stone on the east side of Cullingsburgh Voe, and another in a loose rock to the west of the houses of Cullingsburgh. Professor HEDDLE (20), (10) tells us that he saw "specimens of small fishes, apparently acanthoides, embedded in a fine-grained muddy sandstone; they were stated to occur in a quarry north of Gardie, in Bressay." There is no reason to doubt this record; but, unfortunately, the fishes can no longer be traced (if they were preserved). I made a careful search in all the quarries near Gardie, but could see no remains of fossil fishes. It is clear that the Shetland Old Red Sandstone is by no means so barren as has hitherto been supposed; but to obtain good fossils, great skill and patience, with some measure of luck, will be required.

## THE FAUNA OF THE BRESSAY SANDSTONES.

The fish-remains obtained in these beds have been determined by DR TRAQUAIR to belong to *Asterolepis* (sp.) and *Holonema* (sp. nov.); possibly there are also fragments which may be referred to a species of *Holoptychius*. Of these genera, the first is typically Upper Old Red; it occurs also in beds assigned to that series at Nairn. *Holonema* is a genus founded by NEWBERRY (26) for remains from the Chemung beds (Upper Devonian) of North America. *Holoptychius* is a very characteristic Upper Old Red genus. So far, then, the evidence of the fish fauna points clearly to the Shetland beds belonging to the Upper part of the Old Red system. It is not, however, absolutely satisfactory when closely examined. The *Holonema* is a new species; the *Asterolepis* also is probably new, though as yet not definitely named; and caution is necessary in classifying Old Red faunas in such cases. As an example of this we may quote the typical Lower Old Red genus *Cephalaspis*, which occurs in the Middle Old Red of

Caithness (35) and the Upper Old Red of Canada (36). *Coccosteus* also is known from the whole range of the Devonian or Old Red Sandstone succession (19). It is easy, however, to exaggerate the importance of exceptional cases. More important is the fact that *Asterolepis* is represented by a species as yet undescribed in beds immediately underlying the John o' Groats zone of the Orcadian Old Red in Orkney (4). This indicates that if the Shetland beds be Upper Old Red, they have close relationships to the Orcadian. Similarly, there are grounds for believing that the Nairn beds (18) which contain *Asterolepis* are older than the Elgin, Dura Den, Jedburgh, and Kiltorcan Sandstones, in which *Bothriolepis* and *Holoptychius nobilissimus* occur. The latter must represent the highest portion of the Old Red Sandstone, as in places they pass up conformably into the base of the Carboniferous.

The only other animal remains as yet obtained from the Shetland Old Red Sandstone are *Estheria membranacea* (Pacht) and plant fragments. Of these, the former was first recorded by Sir R. Murchison (22), and was described by Professor Rupert Jones (31). This species is abundant and well preserved in the Orcadian Old Red of Caithness and Orkney. It occurs also in the Devonian of Livland (Livonia) in Russia, but has not been found in the Upper Old Red Sandstone of any part of Great Britain (except Shetland). This is sufficient to indicate that the Shetland beds have close relationships with the Middle Old Red Sandstone.

## The Fossil Flora of the Shetland Old Red Sandstone.

The fossil plants found near Lerwick have been described by many palæobotanists. They are in a most unsatisfactory state of preservation, but (with the exception of Sir Joseph Hooker) (15) all who have examined them have noted their resemblance to the hardly less imperfect plant-remains so numerous in the Middle Old Red of Caithness and Orkney. Recognising that little was definitely known about their real nature, I had specimens forwarded to Dr Kidston, in order to obtain the latest and most authoritative opinion regarding them. He assures me that, whatever may be their botanical affinities, they have nothing in common with the Lower Old Red flora of Forfarshire and Perthshire, or the Upper Old Red floras of Kiltorcan and Roxburghshire. So far as they are determinable, they resemble rather the plants of the Orcadian Old Red. This opinion, though vague, is of value, as confirming the evidence provided by the crustaceans (Estheria) and one of the genera of fishes (Asterolepis).

## Lithology.

The lithological similarity between the Old Red Sandstone of Shetland and that of Caithness and Orkney has been remarked on by various writers. It is best seen in the cliff exposures when viewed from a distance, as the thin-bedded flags of Bressay and Noss, where eroded by the sea, yield cliffs very like those of Orkney. Closer examination,

however, hardly strengthens the comparison. The Shetland beds are coarser, more micaceous, and less uniform than those of Orkney. Clearly they were formed by the denudation of a slaty and gneissose series, like that which forms the axial ridge of Shetland. Evidence of this sort does not carry much weight; but we may note that the Old Red Sandstone of Shetland certainly resembles the Caithness beds in lithological character more closely than the Upper Old Red Sandstone of Hoy, Ross-shire, and the districts south of the Moray Firth.

## Summary.

In speculating on the age of the Shetland beds, the character of the vertebrate fauna is by far the most reliable index; and next to it we may place the evidence of the plants. The former points unmistakably to Upper Old Red conditions, the latter to close affinities with the Orcadian. The conclusions which at the present time we are justified in arriving at may be summarised as follows :—

(1) The Old Red Sandstone beds of Shetland belong to a distinct zone of that system, different from any other yet identified in Britain.

(2) By the evidence of its fossil fishes, it is most naturally placed in the Upper division.

(3) Both the fauna and the flora indicate affinities with the Orcadian or Middle Old Red of Caithness and Orkney, consequently it may be the lowest or one of the lowest zones of the Upper Old Red Sandstone.

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# XIV.—On Fossil Fish-remains collected by J. S. Flett, M.A., D.Sc., from the Old Red Sandstone of Shetland. By Ramsay H. Traquair, M.D., LL.D., F.R.S. (With Two Plates.)

(Read March 18, 1901. MS. received May 8, 1908. Issued separately July 4, 1908.)

Little has hitherto been known about the animal remains of the Old Red Sandstone of Shetland. In 1858 Sir Roderick Murchison mentioned the occurrence, in flaggy beds in the environs of Lerwick, of "the same little Crustacean (the Estheria) which occurs at Thurso and Kirkwall."* Heddle in 1878 refers to the occurrence of fish-remains in the rocks of the same region in the following terms:—"Specimens of small fishes, apparently acanthoides, were shown the writer; these were imbedded in a brown fine-grained muddy sandstone; they were stated to occur in a quarry north of Gardie in Bressay."† Again, in the same year, Sir A. Geikie, in his well-known paper on the "Old Red Sandstone of Western Europe," states that Dr Heddle "informs me that he was shown some ichthyolites (*Coccosteus*, etc.) in Bressay, which he was assured had been found among the flagstones of that island."‡ Unfortunately it does not appear that any description of these specimens has ever been published, nor, so far as I am aware, is their present whereabouts known.

In 1898, however, Dr Flett obtained from the flagstones at Bressay some fragments of undoubted dermal plates of fishes. In the following summer (1899), aided by a grant from the Royal Society of London, the same investigator succeeded in collecting from the same beds a larger number of these remains, which their finder was so kind as to refer to me for study and description. These specimens, though still very fragmentary, were nevertheless good enough, some of them, to afford a clue to their genera; and accordingly, in a brief notice which appeared in *Nature* of November 23 of that year, it was announced that fragments referable to *Holonema*, Newberry, and *Asterolepis*, Eichwald, had been identified by me among Dr Flett's material.

This was of great geological interest, as the first named genus has as yet been only with certainty found in strata of Upper Devonian age, namely, in the "Chemung" rocks of North America. *Asterolepis*, on the other hand, though well known in the Upper Old Red of Scotland and Russia, is also not unknown in the Orcadian series (Middle Old Red of Murchison), Dr Flett and Mr Spence having collected speci-

* *Quar. Journ. Geol. Soc.*, vol. xv., 1858, p. 413.

† "On the Geognosy of Scotland. The Mainland of Shetland," *Mineralog. Mag.*, vol. ii., No. 11, Dec. 1878, p. 156, footnote.

‡ *Trans. Roy. Soc. Edin.*, vol. xxviii., 1878, p. 418.

mens referable to the genus both from the Mainland of Orkney and from South Ronaldshay.

Discussion of the geological position of the Old Red of Shetland I must, however, leave to Dr FLETT, and so I proceed to my own proper task, namely, the description of the fish-remains themselves.

## Class PISCES.

### Subclass OSTRACODERMI.

### Order ANTIARCHA.

### Family ASTEROLEPIDÆ.

### Genus *Asterolepis*, Eichwald.

*Asterolepis*, sp. indet. Pl. I. figs. 1–4.

*Description.*—Owing to the fragmentary and otherwise badly preserved condition of the remains referable to *Asterolepis*, it is impossible to give a definition of the species to which they belong, and consequently I refrain from giving it a name at present.

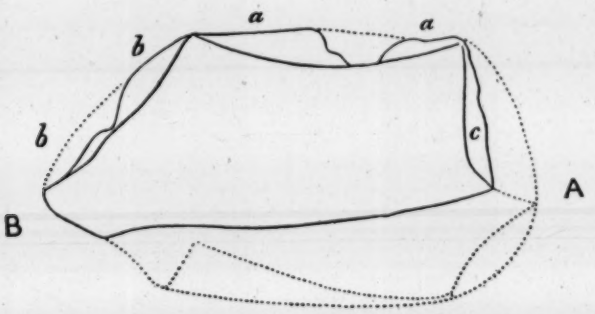



FIG. 1.—Outline of impression of the greater part of left posterior dorso-lateral plate of *Asterolepis*, the missing parts given in dotted lines. A anterior, B posterior extremity ; *a.a.*, area overlapped by anterior median dorsal plate : *b.b.*, area overlapped by posterior median dorsal plate ; *c.*, part of the area overlapped by the anterior dorso-lateral. The lower part of the plate with the areæ overlapped respectively by the anterior and posterior ventro-lateral plates is deficient, and is represented here by dotted lines. Compare with fig. 1 on Plate I.

Fig. 1, Pl. I., is the impression of the outer surface of a plate which is at once identifiable as the greater portion of the *left posterior dorso-lateral* of a fish belonging to the genus *Asterolepis*. Its explanation is given in the text-figure above, in which A is the anterior and B the posterior end of the bone, the missing parts being restored in dotted outline. Now along the upper margin is the imprint of a narrow articular area *aa*, unfortunately broken away a little in the middle. This is the surface overlapped by the anterior median dorsal plate. Then behind this area and along the posterior-superior margin is a second narrow articular area *bb*, namely, that overlapped by the posterior median dorsal. Herein we have the proof that the plate belongs to *Asterolepis*, as in this genus the anterior median dorsal overlaps, as above, the posterior

dorso-lateral, whereas in *Pterichthys* and *Bothriolepis* the reverse is the case, the anterior median dorsal being *overlapped by*, instead of overlapping, the plate in question.*

The impression of the exposed surface of the plate shows evidence of a tuberculated sculpture, but this is not sufficiently well preserved to enable us to compare it with that in any other species.

Three other fragments are undoubtedly asterolepid, and may safely be referred to the same genus and species with the plate described above.

Fig. 2, Pl. I., is recognisable as the anterior part of the left anterior dorso-lateral plate, broken off behind in such a way that the fractured edge shows a backwardly directed point. Most of the bony matter has scaled off, so that the external sculpture is lost. The subjoined text-figure 2 gives the orientation of this fragment, the parts awanting being, as in text-figure 1, indicated in dotted outline. Here the letter *a* indicates the marginal area overlapped by the anterior median dorsal plate, but the area along the opposite (lower) margin, overlapped by the anterior ventro-lateral, is gone.

Fig. 3 shows the *distal* segment of the pectoral limb, split up longitudinally, the

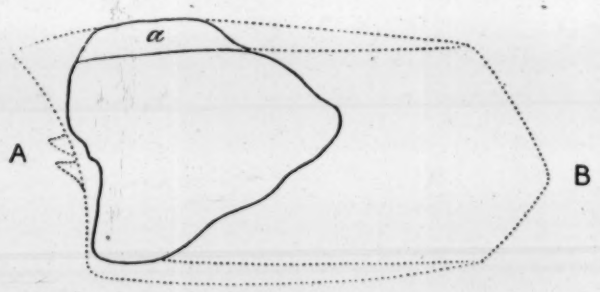



Fig. 2.—Outline of a fragment of the left anterior dorso-lateral plate of *Asterolepis*, the contour being restored in dotted lines. A anterior, B posterior extremity; *a.*, area overlapped by the anterior median dorsal plate.

outer surface being adherent to the matrix. The figure shows as much of its configuration as could be expressed in any description.

In fig. 4 we have the articular element of the *proximal* segment of the pectoral limb. Most of its substance has been lost, and its contour also is not sufficiently perfect to enable us to determine whether it belongs to the right or left limb, or to the dorsal or ventral surface.

*Observations.*—That the remains described above belong to the genus *Asterolepis* of Eichwald there cannot be the remotest doubt, and it is likewise probable that they represent a hitherto undescribed species. However, the scantiness of the material as well as its very fragmentary nature render it impossible to give a satisfactory specific diagnosis, and so, as already remarked, I refrain for the present from giving it a name.

*Locality.*—Bressay, near Lerwick, Shetland; collected by Dr J. S. Flett.

* See the author's paper on the "Structure and Classification of the Asterolepidæ" in *Ann. and Mag. Nat. History* [6], vol. ii. (1888), pp. 485–503. Also in "Fishes of the Old Red Sandstone," pt. ii. No. 1, *Palæontographical Society*, 1894.

*Incertæ Sedis.*

Order ARTHRODIRA.

Family (?) COCCOSTEIDÆ.

Genus *Holonema*, Newberry.

*Generic Characters.*—Imperfectly known. The genus was instituted for thin, rather large plates covered externally by closely set ridges or rugæ radiating from a central point towards the circumference, but often, too, especially in the middle of a plate, irregular or reticulated. The plates as yet known seem to belong to a ventral cuirass of Coccostean structure.

*History.*—In 1883 the late Professor CLAYPOLE described and figured what he designated as a "large fish plate from the Upper Chemung (?) beds of North Pennsylvania."* This plate he considered to be probably the median ventral plate of a species of *Pterichthys*—the "lozenge" plate of HUGH MILLER.

The plate itself is of an oblong pentagonal form, having one very short side placed transversely at the supposed posterior extremity, followed by two pairs of laterally symmetrical sides, of which the shorter pair meet at an angle on the supposed anterior aspect. All round is "a flat, finely striated margin"—namely, the narrow area overlapped by adjoining plates—within which the exposed surface is sculptured with radiating, closely set, subparallel rugæ, more or less perpendicular to the margin, though in the centre of the plate tending to show an irregular reticulation.

This plate, evidently a median one, CLAYPOLE considered to belong to a new species of *Pterichthys*, and to represent the median ventral or "lozenge" plate of HUGH MILLER. Accordingly he named it *Pterichthys* (?) *rugosus*, noting, however, that Professor NEWBERRY, to whom he had sent a photograph and description of the specimen, had informed him in a letter that he (Professor NEWBERRY) "very much doubted if the plate here described belonged strictly to *Pterichthys*, and was inclined to consider it the type of a new genus."

Six years afterwards NEWBERRY, in his special work on the *Palæozoic Fishes of North America*,† figured some further plates of the same fish from the "Chemung" strata, which he felt necessary to separate generically from *Pterichthys*, though retaining CLAYPOLE's name for the species, which he now designated *Holonema rugosum*. In Pl. XVII. of the work he reproduces CLAYPOLE's figure (fig. 2) and adds representations of three other pieces. In fig. 1 we have a rather large fragment, in which the rugæ, frequently bifurcating, radiate from nearly a central point, while in fig. 4, obviously a fragment, the point of radiation is at one side; lastly, in the remaining fragment, shown in fig. 3, the rugæ are in some places contorted and irregular. It is to be noted that, although NEWBERRY nowhere directly states his opinion as to the

* *Proc. American Phil. Soc.*, vol. xx. (1883), pp. 664–666, with figure.

† *Palæozoic Fishes of North America* (Washington, 1889), pp. 92–95, pl. xvii. figs. 1–4.

systematic position of *Holonema*, he very significantly compares CLAYPOLE's original specimen with "the lozenge-shaped plate of *Coccosteus*; the ventro-median plate of Owen."

Professor CLAYPOLE in the following year returned to the subject in a paper entitled "Palæontological Notes from Indianopolis."* Here he states that a second plate, evidently a lateral one, had come into his possession, and also that Professor H. S. WILLIAMS had obtained a new and unique specimen from the Catskill of New York, consisting of several large plates of *Pterichthys rugosus*, CLAYPOLE. He gives a restored outline of the cuirass, here reproduced, text-fig. 3, from which it will be seen that behind, or supposed to be behind, the original central plate is a posterior median one, while two pairs of lateral ones complete the sides. Quoting Professor NEWBERRY's opinion that the characters justify a separation from *Pterichthys*, he says that, "for the present,

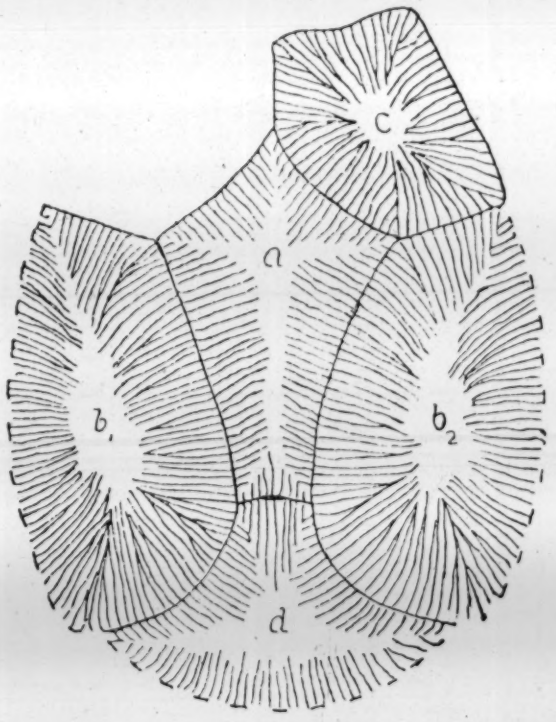



FIG. 3.—Ventral cuirass of *Holonema rugosum*, supposed by Claypole to be the dorsal shield of a species of *Pterichthys* or allied genus. From Prof. Claypole's paper in the *American Geologist* quoted above. The nomenclature of the plates given by him is—*a*, dorso-median (first described); *c*, dorso-lateral left; $b_1$ post-dorso-lateral right; $b_2$, post-dorso-lateral left; *d*, post-dorso-median.

According to Dr SMITH WOODWARD's view, obviously the correct one, that this cuirass is the ventral shield of a Coccostean turned the wrong way, these plates would read—*a*, median ventral; *d*, anterior median ventral; $b_1$ and $b_2$, anterior ventro-laterals; *c*, posterior ventro-lateral.

however, the matter must remain undetermined and the fossil be called *Pterichthys* (*Bothriolepis*) *rugosus* or *Holonema rugosum*." It is, however, clear that CLAYPOLE still believed in the Pterichthys theory, and also that he now looked on the plates in his figure as being *dorsal* instead of ventral; for he says, "The form of the central plate, the presence of another median plate at its narrow end, the form, size, and fit of the lateral plates at its wide end, the direction of the wrinkles, and the number of plates

* *American Geologist*, vol. vi. (1890), pp. 255–258.

necessary to complete the shield (assuming its near relationship to *Pterichthys* and *Bothriolepis*, which seems reasonable) all combine to indicate the dorsal rather than the ventral aspect of the fish."

But in 1891 Dr SMITH WOODWARD, in the second part of his "Catalogue" (pp. 314–315), unhesitatingly classes the genus as Coccostean, pointing out the resemblance in form between the median plate figured by CLAYPOLE and NEWBERRY and the median ventral of certain species of *Coccosteus*, e.g. *C. disjectus*; holding also that "the recent description of the complete ventral shield by CLAYPOLE proves that it agrees with that of *Coccosteus* in every essential particular. The 'post-dorso-median' plate of CLAYPOLE is obviously the anterior median ventral, while the 'post-dorso-lateral' and 'dorso-lateral' of the same author are the anterior and posterior ventro-lateral plates respectively." The cuirass figured by CLAYPOLE is in effect a Coccostean plastron turned the wrong way.

In the same year Professor E. D. COPE* mentioned a specimen of the genus from Mansfield, Tioga County, Pennsylvania, namely, a lateral plate of the plastron. He also states: "Besides this there is a nearly complete pectoral spine, which is of much interest, as this part of the skeleton has not been previously known. . . . . The spine differs from that of both *Bothriolepis* and *Pterichthys* in being without complete segmentation. It is continuous throughout to the apex. This then will constitute the generic distinction so far known between *Holonema* and *Bothriolepis*." Of this supposed spine of *Holonema* a figure is given, which at once betrays to the eye of anyone familiar with the structure of the Asterolepidæ that it is not an entire appendage but merely the distal portion or segment of the pectoral limb of *Bothriolepis*.

In another paper† published in 1892 COPE figured and described as *Holonema rugosum* a plate which he considered to belong to a new species. As regards the genus, he still looked upon it as belonging to the Antiarcha, but with *two ventral median plates*, thus differing from *Bothriolepis*. He also described without figure a plate which he referred to *H. rugosum*, saying regarding it: "This piece, together with the pectoral limb which I have already described, demonstrates the position of the genus to be with the Antiarcha and not with the Arthrodira as has been suspected by Mr A. S. WOODWARD."

Dr SMITH WOODWARD,‡ however, in a review of the first of COPE's two papers, reaffirmed that "the so-called dorsal shield of *Holonema* is really the ventral shield turned the wrong way forwards; and the genus belongs to the Arthrodira, not to the *Ostracodermi*." Further, that "the limb referred by Professor COPE to *Holonema* is the distal segment of the arm of *Bothriolepis*, originally named *Stenacanthus* by LEIDY."§ That he was right in the second statement goes without saying; and as

* *Proc. Am. States National Museum*, vol. xiv. (1891), pp. 447–463.

† *Proc. Am. Phil. Soc.*, vol. xxx. (1892), pp. 221–229, pls. vii. and viii.

‡ *Geol. Mag.* (3), vol. ix., 1892, pp. 233–235.

§ It will also be remembered that Agassiz himself was deceived by the corresponding element in *Bothriolepis major*, from the north of Scotland, which he figured, under the name of *Placothorax paradoxus*, as "un type nouveau de la famille des Céphalaspides." (Poiss. Foss. vieux grès rouge, p. 134, tab. 30 *a*, figs. 22, 23.)

regards the first, there can be no doubt that his explanation of the facts known about *Holonema* is by far the most probable one.

Consequently we place *Holonema* in the order Arthrodira, though in what special group or family it is still impossible to say. Whether *Phyllolepis*, the remains of which likewise consist of thin plates with a rugose sculpture, also is referable to the same order, remains for future discussion.

*Distribution.*—Plates certainly referable to *Holonema* have hitherto been found in the United States, and there only in strata of Upper Devonian age. The "Chemung" rocks of the States of New York and Pennsylvania are cited as the source of these specimens, for though CLAYPOLE first stated regarding Professor H. S. WILLIAMS's specimen that it was from the "Catskill," he also said that "it is right to add that the exact horizon of the fossils is a little uncertain. They came, however, from either the highest beds of the Chemung or the lowest of the Catskill."

Dr SMITH WOODWARD, however, in his "Catalogue," part ii. p. 315, mentions that "so far as can be determined from the description and imperfect figures, the dermal plates from the Devonian of the Eifel named *Coccosteus obtusus*, Koenen, exhibit much resemblance to those of *Holonema*." I have carefully read Professor VON KOENEN'S description * and examined his figures (the latter are certainly imperfect enough), but am very doubtful as to the relationship to *Holonema* of the pieces depicted, especially as their radiating striæ are said to be "on the under side." The words are: "Diese Platten zeigen einerseits eine unregelmässige feine Streifung parallel ihrem Aussenrande, und andererseits *auf der Unterseite* eine feine von einem Puncte ausstrahlende Streifung, welche indessen an je einer langen Seite sich steil gegen diese umbiegt." It would be necessary to re-examine the originals to come to a definite conclusion on the matter.

*Holonema ornatum*, sp. nov., Traquair. Pl. II.

*Specific Character.*—The marginal radiating ridges are ornamented each with a row of minute ganoid tubercles.

*Description.*—Only two fragments have occurred. The first of these is represented in Pl. II. fig. 1, and is evidently a portion of what must have been originally a plate of considerable dimensions. It shows the marginal band of ridges very well, but the central part of the plate has come off with the counterpart. The band is about 1 inch in breadth, and consists of ridges which are mostly parallel with each other and perpendicular to the free margin of the plate, except at one extremity (the upper in the figure), where they are rather oblique. At the opposite extremity of the fragment a small part of the central area is seen, and there the ridges become oblique and irregular. Where they are regular, from nine to ten may be counted in the $\frac{1}{2}$ inch transversely. Each of these ridges is ornamented with one row of minute, rounded, brilliantly ganoid tubercles.

* *Verh. naturh. Verein. preuss. Rheinl.*, vol. xliii. (1886), pp. 55–57, with two figures.

In fig. 2 we have the counterpart of the above-described fragment, which shows a slightly larger extent of surface. In the central area of the plate the bone has adhered closely to the matrix, so that the impression of the sculpture of that part is shown only along a narrow portion on the right side; and here, as noted above, the ridges become oblique and irregular as compared with their tolerably close parallelism in the marginal band.

In fig. 3 we have another fragment of quite an irregular shape, namely roughly triangular, and measuring 6 inches in greatest length by $3\frac{1}{2}$ in greatest breadth. Of the three margins, one (the lower in the figure) is nearly straight and may well be considered to have been an original margin, as also may the shorter irregular one on the left side; while the remaining border marks, of course, the line where the plate is cut off by the edge of the stone.

Like the previously described plate, its surface is proportionally thin, its thickness at the thickest part being only $\frac{1}{10}$ of an inch. Only towards the short margin is the external sculpture shown, and this consists mostly of comparatively coarse, plain, reticulating ridges, which become finer towards the margin of the plate, and there exhibit evident traces of a beaded ornament similar to that which has been noted in the first described specimen.

As the above described two pieces are mere fragments, it is scarcely possible to locate them accurately on the body of the fish. I should, however, be inclined to suppose that the first (figs. 1 and 2) belonged to the ventral carapace, and is in fact a fragment of the anterior or posterior part of the anterior ventro-lateral plate marked $b_1$ in text-figure 3.

*Observations.*—The sculpture of the first described specimen, which shows prominently a marginal band of ridges nearly parallel with each other and nearly at right angles with the edge of the plate, together with the great proportional thinness of the bone, indicate *Holonema* of Newberry as the genus to which it ought to be referred, while the beaded ornament of the ridges supplies us with a tangible specific mark. As regards the second example, we note first, that although the marginal band of parallel rugæ is not visible, owing to the surface of the bone along nearly the whole of the long margin having come away with the counterpart, yet the distinct occurrence of the minute bead-like tubercles on some of the finer reticulating ridges which *are* exposed indicates that this second plate belongs to the same species as the first.

*Locality.*—Bressay, near Lerwick, Shetland; collected by Dr J. S. Flett.

### Undetermined Fragments.

The residue of the collection consists of fragmentary dermal plates of fishes, which are really unnameable, as their contour affords no clue to their original shape, nor is there anything in their sculpture of a really determining character. Of these I have figured three examples.

Fig. 5, Pl. I., is an angular fragment showing two overlapped facets and a large

portion of free surface, which latter is marked with ill-defined rugæ, reminding us somewhat of the ornament of a scale of *Holoptychius*. I have, however, no remembrance of having ever seen a *Holoptychius* scale with overlapped facets so sharply marked off from the sculptured area, and ordinarily the overlapped portion of such a scale forms an area of much larger proportional extent.

Fig. 6 is a fragment concerning which still less can be said. It is an absolutely irregular five-sided piece seen from the internal or concave aspect, but a certain amount of a rugose ornament shows through from the outer surface. These rugæ are arranged in three groups or areæ, and are, within the limits of each area, parallel to each other but at angles to those of adjacent areæ, as is well seen in the figure. I cannot venture any theory as to the identification of this fragmentary plate.

The contour of the fragment shown in fig. 7 reminds us superficially of one of the posterior ventro-laterals of *Coccosteus*, but there is no real evidence that this shape represents that of the plate in its original entirety. At the upper left-hand corner, however, where the surface is better preserved than over the rest of the specimen, a few bright and smooth stellate tubercles are seen, which are not unlike those of a Coccostean plate.

## EXPLANATION OF THE PLATES.

[In these Plates all the figures are of the natural size.]

### Plate I.

Fig. 1. Impression of outer surface of left posterior dorso-lateral plate of an undetermined species of *Asterolepis*, the lower margin being deficient. For orientation see text-figure 1, p. 322.

Fig. 2. Anterior part of a broken anterior dorso-lateral plate of *Asterolepis* from which most of the bony matter has flaked off. For orientation see text-figure 2, p. 323.

Fig. 3. Distal segment of pectoral limb of *Asterolepis*.

Fig. 4. Articular element of proximal segment of pectoral limb of *Asterolepis*.

Figs. 5, 6, 7. Undetermined fragments.

### Plate II.

Fig. 1. Fragment of a large plate of *Holonema ornatum*, Traq., showing the sculpture along the free margin.

Fig. 2. Counterpart of the same specimen.

Fig. 3. Fragment of another large plate, with sculpture more of a reticulated pattern.

DR TRAQUAIR ON FOSSIL FISHES FROM SHETLAND. PLATE I.

Fig. 1.

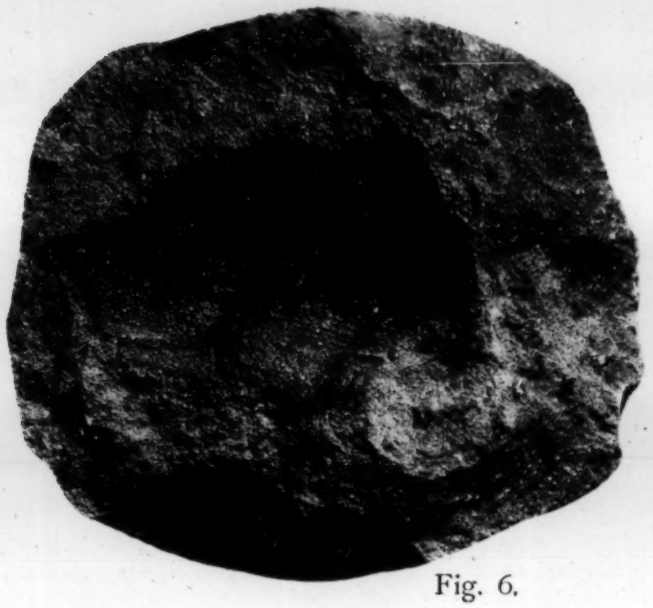


Fig. 6.

Fig. 2.

Fig. 4.

Fig. 3.

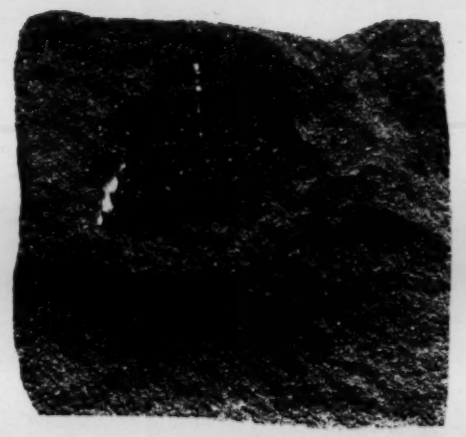


Fig. 5.

Fig. 7.

DR TRAQUAIR ON FOSSIL FISHES FROM SHETLAND. PLATE II.

Fig. 3.

Fig. 2.

Fig. 1.

# XV.—On the Lamellibranch and Gasteropod Fauna found in the Millstone Grit of Scotland.

By Wheelton Hind, M.D., B.S., F.R.C.S., F.G.S. *Communicated by* Dr J. Horne, F.R.S. (With Two Plates.)

(MS. received February 12, 1908. Read March 16, 1908. Issued separately September 2, 1908.)

## PART I.

### Introduction.

During the revision of the Midlothian coalfield by the Geological Survey, special attention was directed to the plant remains occurring in the Millstone Grit, with the view of obtaining evidence bearing on the probable boundary line between the Upper and Lower Carboniferous rocks. Mr Tait collected a number of plants from certain horizons in this division of the Carboniferous system, which were submitted to Mr Kidston, F.R.S., for determination. Those from the lower part of the Millstone Grit were regarded by Mr Kidston as belonging to the Lower Carboniferous flora, and those from the upper portion, to the Upper Carboniferous flora. While carrying on his work in the field, Mr Tait found certain fossiliferous bands in the basal portion of the Millstone Grit, charged with lamellibranchs, brachiopods, and other marine organisms, and associated with Lower Carboniferous species of plants. These observations were of service in tracing the base line of the Upper Carboniferous rocks round a large part of the Midlothian basin. It ought to be clearly understood, however, that this boundary line is based solely on the evidence supplied by the plants and fishes as determined by Mr Kidston and Dr Traquair respectively.

When the revision of the Midlothian area was completed, certain sections of the Millstone Grit in the counties of Linlithgow, Lanark, and Stirling were examined by Mr Tait, to see if they might furnish confirmatory evidence of the boundary line adopted in Midlothian. Owing to the economic importance of the fireclays in this division in Lanarkshire, which has led to extensive boring operations, the sequence of the lower part of the strata in that district is now well known. In the basal portion there are fossiliferous bands containing marine organisms just as in Midlothian. Though Lower Carboniferous plants have not been found in this division in the districts of Glenboig, Castlecary, or Torwood Glen, yet they have been met with in beds a little above the base of the Millstone Grit at Glasgow, and Upper Carboniferous plants have been obtained in the upper part of this division at Castlecary. It seems reasonable to infer, therefore, that the lower part of the Millstone Grit in the counties of Lanark, Linlithgow, and Stirling is on the same stratigraphical horizon as the basal portion in Midlothian with its marine bands and Lower Carboniferous flora.

While collecting the plants Mr TAIT obtained a large number of specimens of Lamellibranchiata, which were sent to me for identification. These were found in beds exposed in the Greenfoot Quarry, near Glenboig Station, Lanarkshire (Sheet 31, one-inch map); in the river Avon, Linlithgowshire (Sheet 31); in Torwood Glen, Stirlingshire (Sheet 31)*; and in Bilston Burn, Midlothian. At each of these localities the lamellibranch fauna was found not far below the line which has been drawn between the Upper and Lower Carboniferous floras, in accordance with Dr KIDSTON's determinations.

I was much surprised to meet with a lamellibranch fauna of which quite 50 per cent. of the species were, as far as I could discover, new to Europe, but which resembled very closely the lamellibranch fauna of the Coal Measures of Nebraska and Illinois of North America.

The most striking member of the fauna was the shell *Prothyris elegans*, Meek, this being the first occurrence of the genus in the Carboniferous rocks of Great Britain. DREVERMANN has described one species, *P. bergica*, from the lowest Carboniferous rocks of Germany, *Zeitsch. der Deutsche Geol. Gesel.*, vol. xiv., 1902, p. 498, pl. xiv. In many cases it was impossible to distinguish any characters sufficient to separate the Scotch and American species from each other, but it may be said that the faunas are generically the same. Moreover, the lamellibranch fauna shows a marked approach to Permian types.

In North America the fauna is accompanied by *Fusulina* and *Meekella*, two fossil genera which are absent in the West of Europe; but both occur in the *Spirifer mosquensis* zone of Russia, a zone which succeeds that of *Productus giganteus* in that country. There does not, however, seem to be the least connection between the fauna of the *Spirifer mosquensis* zone and that under examination. It is important to ascertain the horizon at which this interesting fauna occurs in Scotland, that it may be known where to look for its representatives elsewhere. At the outset there is a great difficulty, and one that must be grappled with in the near future.

The Lower Limestone series of Scotland contains the same coral fauna as the uppermost division of the Carboniferous Limestone of England, or its equivalent farther north, the Yoredale series, that is to say, the *Dibunophyllum* zone. The question at once arises, What are the homotaxial equivalents of the Edge Coal series and the Upper Limestone series of Scotland, south of the Border? This question can only be satisfactorily settled on palæontological lines.

There is the most striking difference between the lamellibranch fauna of the Scotch beds assigned to the Millstone Grit, and that which characterises the Millstone Grits and the Pendleside series of England and Ireland. Here the upper beds of Carboniferous Limestone, the *Cyathaxonia* beds, which themselves are the highest subdivisions of the *Dibunophyllum* zone, are succeeded by black shales and limestones with

* A preliminary statement referring to this collection of lamellibranchs was published in the Summary of Progress of the Geological Survey for 1905, pp. 147 and 148.

*Pterinopecten papyraceus*, Sow., sp., *P. carbonarius*, Hind, *Posidonomya Becheri*, Bronn, *P. membranacea*, M'Coy, *Posidoniella lævis*, Brown, sp., *Leiopteria longirostris*, Hind; and the black shales which intervened between the different grits of the Millstone Grit series yield *Pterinopecten papyraceus*, Sow., sp., *Posidoniella lævis*, Brown, sp., *P. minor*, Brown, sp., *Sedgwickia attenuata*, M'Coy, *Sanguinolites ovalis*, Hind, *Myalina verneuillii*, M'Coy, *Myalina Flemingi*, M'Coy, *Schizodus antiquus*, Hind, *Nucula æqualis*, Sow., *Nuculana stilla*, M'Coy, *Ctenodonta lævirostris*, Portlock, sp., the majority of which have not yet been found in Scotland. On the other hand, I have seen goniatites typical of the Upper Carboniferous beds of the Midlands, in the collection of Mr Neilson; *Dimorphoceras Looneyi*, Phill., sp., *D. Gilbertsoni*, Phill., sp., from shale over the Hosie Limestone; *Glyphioceras reticulatum*, Phill., sp., from Gair; *G. Phillipsii*, Foord and Crick, from Thornliebank; and from East Kilbride, *G. vesica*, Phill., sp., and *Pterinopecten papyraceus*, Sow., sp. These species never are found in England until the close of the Carboniferous Limestone period, and always occur in beds which succeed rocks which have the coral fauna of the Lower Limestone series. I mention these facts that the importance of the whole question may be recognised, and with the idea that they may possibly lead to a solution of the long open question of the difference of the Carboniferous sequence in Scotland and England.

The brachiopod fauna is not rich in species, but indicates a late period of Carboniferous time. The special forms of the various species are identical either with those that occur in the very fossiliferous quarry 300 feet below the Millstone Grit at Congleton Edge, Cheshire, in connection with the *Glyphioceras spirale*, Phill., sp., beds, or in black shales which lie on the upper beds of Carboniferous Limestone in the Upper Nidd valley. The most interesting specimens in this connection are the numerous specimens of *Schizophoria resupinata*, Mart., sp., where some of the fine radiating lines which form the ornament of the shell terminate in small raised points as if there was an attempt to form a spine. This character is well marked in the Scotch and Congleton Edge shells. There is a species of *Lingula* which I suspect to be new to science.

The Cephalopoda are represented by a single species, which I doubtfully refer to *Glyphioceras Phillipsii*, Foord and Crick. The specimen is fragmentary, and is a cast of the outer surface of the shell, and does not show any sutures. The absence of Cephalopoda at this horizon is very marked compared with their abundance throughout the Pendleside series and the shales of the Millstone Grits of England and Ireland.

The Gasteropoda show a strong relation to the North American fauna. Several species I regard as identical with those figured and described from the Coal Measures of Nebraska.

Mr Tait writes me that he "obtained no plants in the marine beds in the Greenfoot Quarry, in the Avon section, nor in Torwood Glen, but in Garngad Road, Glasgow, plants belonging to the Lower Flora occur in beds 50 to 100 feet above the Castlecary Limestone." "From the upper part of the Millstone Grit at Castlecary, plants belong-

ing to the Upper Flora were obtained, so that the horizon at which the flora changes is almost the same level as that in Midlothian. I think that all the lamellibranchs

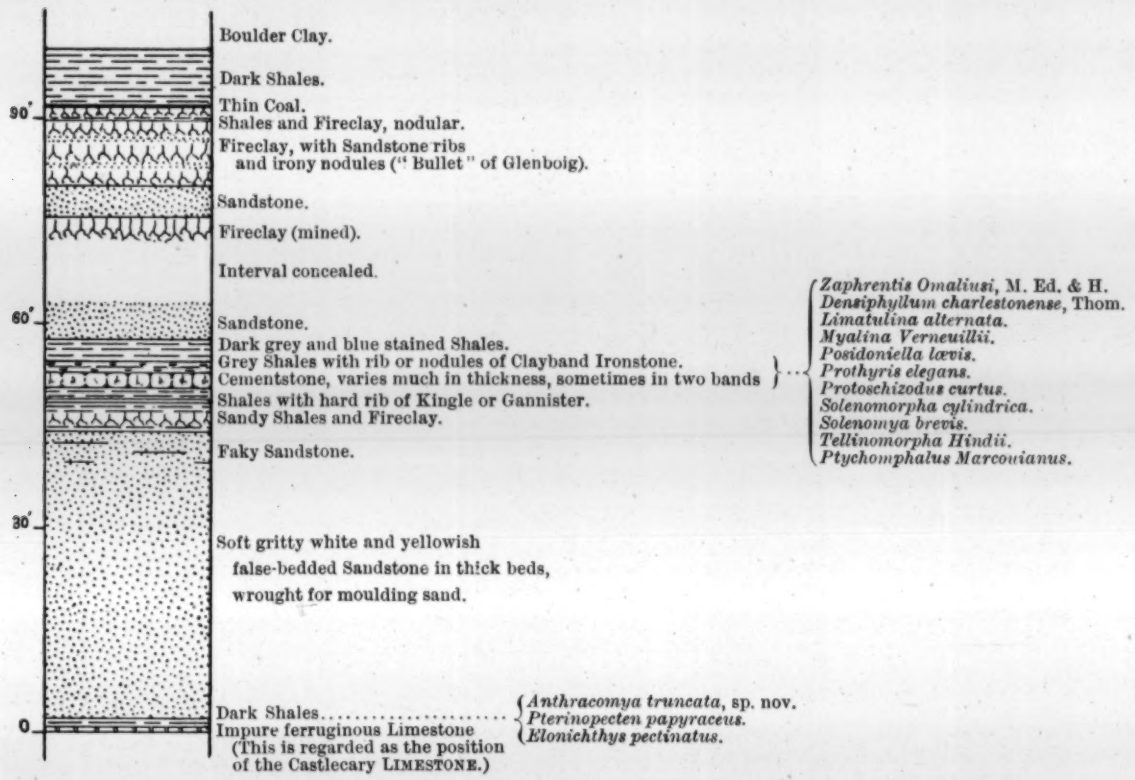



FIG. 1.—Vertical Section of Strata at Greenfoot Quarry, near Gain Farm, 3 miles N. of Coatbridge.

were obtained from beds containing a Lower Carboniferous flora, and just below the point where the Upper and Lower floras meet."

Certain species which were found to occur in the Basement beds of the Bristol

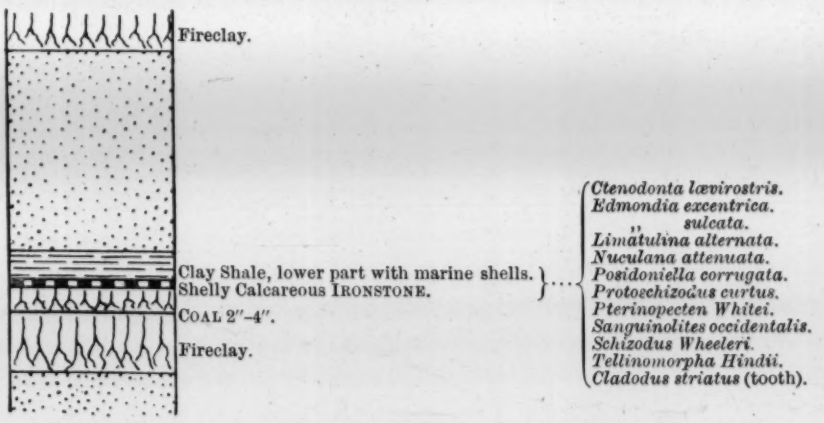



FIG. 2.—Section on the North Bank of the River Avon, West of the Railway Viaduct, 2½ miles W.N.W. of Linlithgow. Scale, 1 inch = 30 feet.

Coalfield were sent to me by Mr BOLTON for my opinion. Amongst them I recognised three species which were common to those beds and the Millstone Grit of Scotland, namely, *Palæolima retifera*, Shumard, *Grammatodon tenuistriatus*, M. and H., sp.,

and a new form named by Mr BOLTON *Tellinamorpha Hindii*. His paper is published in the *Quart. Journ. Geol. Soc.*, vol. lxiii. p. 445.

The annexed vertical sections illustrate the order of succession of the strata at the localities where the lamellibranchs were obtained; the one at Greenfoot Quarry has been kindly supplied by Mr HINXMAN, the second and third on the river Avon

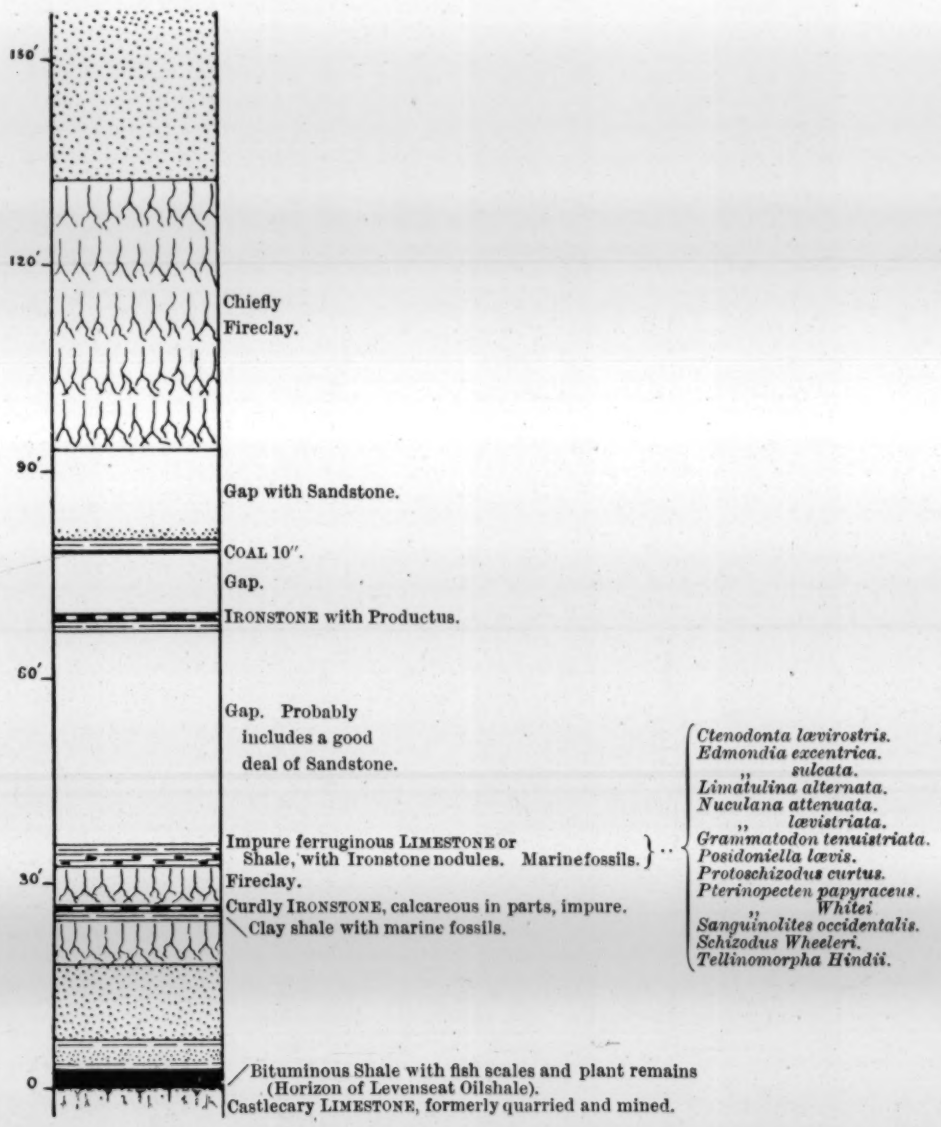



FIG. 3.—Section on the Banks of the River Avon, East of the Railway Viaduct a mile N. of Manuel Junction. One-inch Map 31. Scale, 1 inch = 30 feet.

by Mr CLOUGH, the fourth at Torwood Glen by Mr TAIT, and the fifth in Bilston Burn by Mr CLOUGH, and I owe a debt of thanks to Dr LEE for references to the discovery of *Prothyris* by DREVERMANN in Germany.

It is certain that the fossiliferous horizon indicated in the shorter section lies above those shown in the larger one, but, owing to the variability of the beds and an obscure fault, its exact distance above these horizons is doubtful. It cannot,

however, be lower than the thick fireclay, and it may be 30 or 40 feet above the top of it.

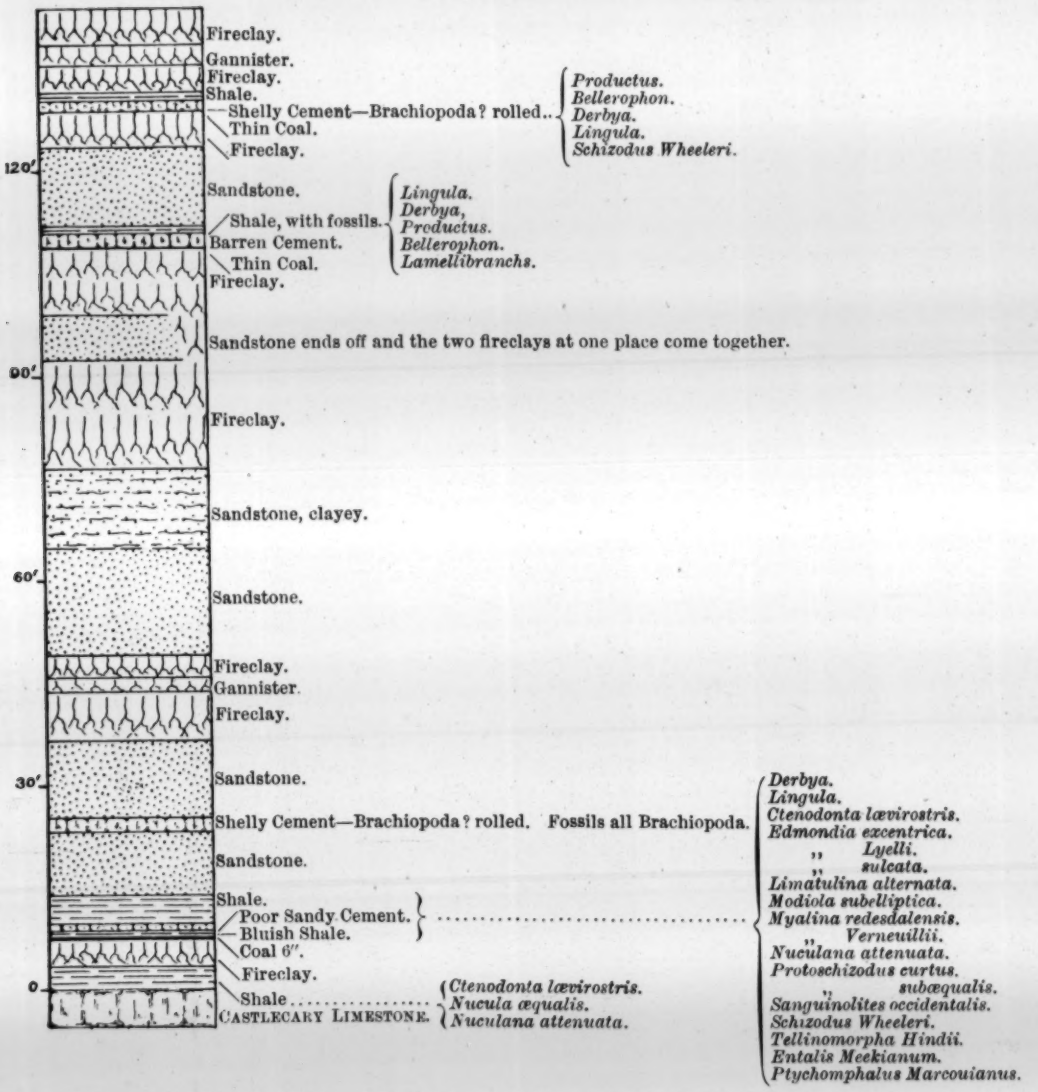



FIG. 4.—Section of Millstone Grit in Torwood Glen, 2½ miles N.W. of Larbert, Stirlingshire. One-inch Map 31. Scale, 1 inch = 30 feet.

Specimens T2143[B] – 2150[B], from Glencryan, 1½ miles S.S.E. of Cumbernauld, One-inch Map 31, include the species—

*Posidoniella lævis*, or *P. corrugata*.

Specimens T2176[B] – 2178[B], from Glencryan—as above, but lower in the series—contain— ? *Edmondia Lyelli*.

Specimens T2214[B] – 2243[B] are from the Fireclay Works, ¾ mile a little N. of E. of Castlecary Railway Station, Stirlingshire. One-inch Map 31.

The following species were obtained here: *Sanguinolites*, sp., *Palæolima retifera*, Shumard, sp., ? *Edmondia Lyelli*, Hind. This mine is sunk to the Castlecary Lime-

stone, so there is no doubt the beds from which these fossils were obtained overlie it, though the bed has not been recognised *in situ*.

Upper Carboniferous plants were got in this mine at 270 feet above the Castlecary Limestone. The species determined by Mr KIDSTON are *Sigillaria elegans*, Sternb. (abundant), *Lepidodendron obovatum*, Sternb., *Lepidodendron aculeatum*, Sternb.

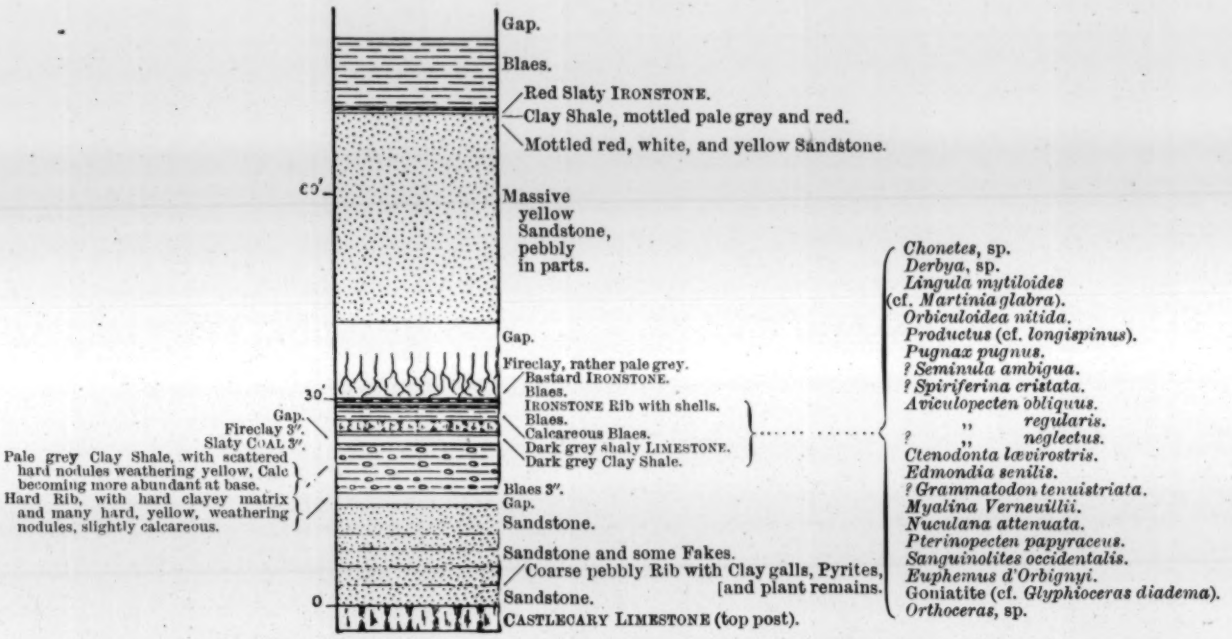



FIG. 5.—Vertical Section of Strata in Bilston Burn, near Polton, Midlothian.

## PART II.

### SPECIFIC DESCRIPTIONS.

*Palæolima retifera*, Shumard, sp., 1858. (Pl. I. fig. 1.)

*Lima retifera*, Shumard, 1858, *Trans. St Louis Acad. Sci.*, vol. i. p. 214.
" " Geinitz ?, 1866, *Carb. und Dyas in Nebraska*, p. 36, pl. ii. figs. 20, 21.
" " Meek and Hayden, 1872, *Fin. Rep. U.S. Geol. Surv. Nebraska*, p. 188, pl. ix. fig. 5.
*Palæolima retifera*, Bolton, 1907, *Q. J. Geol. Soc.*, p. 462, pl. xxx. fig. 10.

*Specific Characters.*—Shell small, oblique, triangularly ovate, very moderately gibbose. The anterior border only slightly curved, the inferior broadly rounded, the posterior oblique and almost straight. The hinge line is short and straight. The umbones are subcentral and small. The anterior ear is small, compressed, triangular; the posterior very similar, and almost the same size. The valve is flattened near the anterior border and expands gradually so that the greatest convexity is near the posterior border, where the valve becomes bent on itself so as to form a flattened posterior surface.

*Interior.*—The shell is ornamented with many angular radiating ribs, somewhat

irregular in distribution, and those towards the posterior margin stouter than those in front. Occasionally ribs may bifurcate, but more frequently new ones arise between any pair. These ribs are crossed by fine concentric lines of growth. The ears are almost smooth.

*Dimensions.*—Pl. I. fig. 1. Specimen No. T2218[B], a right valve, measures: antero-posteriorly, 12 mm.; dorso-ventrally, 14 mm.

*Localities.*—Bed in pit shaft at Castlecary Fireclay Works.

*Observations.*—There is one specimen of this shell in the collection which I have referred to SHUMARD'S species. The very elaborate description and excellent figures given by MEEK and HAYDEN leave nothing to be said in addition. The British species most closely related is *Palæolima simplex*, Phillips. This shell is less triangular, comparatively broader, and has fewer but broader and less angular radiating ribs. MEEK and HAYDEN, following SHUMARD, refer their shell to *Lima*, but I have shown that the Carboniferous forms differ in certain details (*Brit. Carb. Lamell.*, vol. ii. p. 39) from typical *Limas*, and created the genus to receive them. The occurrence of the genus in rocks of Millstone Grit age in Scotland somewhat extends our knowledge of the vertical range of the genus.

*Limatulina alternata*, M'Coy, sp., 1844. (Pl. I. figs. 9, 10.)

*Limatulina alternata*, Hind, 1903, *Brit. Carb. Lamell.* (Pal. Soc.), vol. ii. p. 39, pl. xix. figs. 7–10, 12.

Seven examples of this shell have been obtained, five of which occurred in an impure ferruginous limestone or cement in the river Avon, between the Railway Viaduct and the outcrop of the Castlecary Limestone, in the county of Linlithgow. Some of the specimens are full grown and show no tendency to dwarfing or senile characters. For further details, my work on Carboniferous lamellibranchs (*op. supra cit.*) may be consulted. The figured specimens are numbered T1888[B] and T1818[B].

*Pterinopecten Whitei*, Meek, sp., 1872. (Pl. I. figs. 11–13.)

*Aviculopecten Whitei*, Meek, 1872, *Fin. Rep. U.S. Geol. Surv. Nebraska*, p. 195, pl. iv. fig. 11, *a*, *b*, *c*.

*Specific Characters.*—Shell below medium size, subordinately quadrate, the left valve moderately convex, the right valve flattened. The anterior and lower borders rounded. The posterior bluntly rounded below, slightly sinuous above. The hinge line straight, meeting the posterior border with a well-marked angle. The umbones are small, pointed, flattened, not elevated, placed far forward. The anterior ear is small, somewhat angular, well defined from the valve by a deep sulcus, deeper in the right valve than in the left. There is no posterior ear, but the upper and posterior part is compressed and subalate. The surface is ornamented by flattened, flexuous, radiating ribs, irregular in size, being crowded and narrow anteriorly, broader and

more widely separated over the middle portion of the valve, becoming very fine and close on the compressed part of the valve, so as to appear obsolete to the naked eye. These radiating ribs are crossed by concentric, irregularly distributed lines and rugæ of growth.

*Dimensions.*—Pl. I. fig. 11. Specimen No. T2982[B] measures: antero-posteriorly, 15 mm.; dorso-ventrally, 14 mm.

*Localities.*—Linlithgow, river Avon, E. side of the Railway Viaduct, 35 to 40 feet above the Castlecary Limestone.

*Observations.*—A number of specimens of this species have been obtained, but from only one of the localities. The species agrees with the description given by Meek (*op. supra cit.*), but is somewhat larger than his figured specimens. In the adult state the posterior margin becomes sinuous above, a fact not indicated in the small American specimen. The species has some affinity to *P. carbonarius*, Hind, but the ribs are broader and flatter and more flexuous, and more interrupted by concentric lines of growth. The distribution of *P. carbonarius* extends from fairly low down in the Pendleside series to the middle of the Coal Measures.

### *Pterinopecten papyraceus*, Sow., sp.

I refer two fragments to this well-known species, one from the Linlithgow and the other from the Gair locality. Undoubted specimens, however, were obtained from the Bilston Burn. I feel fairly satisfied with my diagnosis, even in the fragmentary state of the specimens. It is at this horizon that I should expect the species to occur in force. In the Midlands it occurs immediately above the upper beds of Carboniferous Limestone or the beds denoted by the coral genera *Cyathaxonia* and *Amplexizaphrentis*.

### *Aviculopecten carboniferus*, Stevens, sp., 1858. (Pl. I. fig. 14.)

*Pecten carboniferus*, Stevens, 1858, *Amer. Journ. Sci. and Arts*, vol. xxx. p 261.
„ *Broadheadii*, Swallow, 1862, *Trans. St Louis Acad. Sci.*, vol. ii. p. 97.
„ *Hawni*, Geinitz, 1866, *Carb. und Dyas in Nebraska*, p. 36, pl. ii. fig. 19, *a*, *b*.
*Aviculopecten carboniferus*, Meek and Hayden, *Fin. Rep. U.S. Geol. Surv. Nebraska*, p. 193, pl. iv. fig. 8; pl. ix. fig. 4, *a*, *b*.

*Specific Characters.*—Body of the shell triangularly ovate, convex, greatest length and breadth equal. The hinge line is moderately elongate, the umbones pointed, raised, and central. The inferior border is broadly rounded, the margin interrupted by the projection of the ribs as pointed processes. The anterior ear is large, compressed, somewhat rolled, its upper border projecting and its anterior edge prolonged into a point; the posterior ear larger than the anterior, pointed, its margin falcate. The ears are separated from the body of the valve by a deep concave sulcus.

*Exterior.*—The surface is ornamented with few (15) distant, regular, raised, rounded ribs, occasionally nodulose when they are crossed by transverse lines of growth. These ribs project beyond the lower margin in the form of spines.

*Dimensions.*—Pl. I. fig. 14. Specimen No. 15,731, a left valve, measures: antero-posteriorly, 18 mm.; dorso-ventrally, 17 mm.

*Locality.*—Millstone Grit of Hazel Hill, 5 miles N.E. of Pately Bridge, Yorkshire; and possibly Congleton Edge Quarry, Cheshire.

A single specimen, a left valve, is in the collection of the Geological Survey, Jermyn Street, from the Millstone Grit of Hazel Hill, Yorkshire.

*Observations.*—The specimen which I now refer to this species is fairly well preserved, but has the tips of each ear wanting. At the lower margin the ribs are seen to project as spines, but the matrix is too hard and coarse to make out whether the spines curved upwards as they are shown to do in MEEK and HAYDEN's figure. The only other British Carboniferous example which is known to have had projecting ribs is *A. Murchisoni* (*Brit. Carb. Lamell.*, vol. ii. pl. xiv. fig. 4), a species which more closely resembles the American shell than any other of the genus. MEEK and HAYDEN describe the right valve as nearly flat, with surface markings as in the left valve but more obscure.

Two fragments in my possession from the Congleton Edge Quarry, upper part of the Pendleside series, probably belong to the species, although not present in the Scotch collection. I have inserted the description of *A. carboniferus* here because it is a member of the American fauna.

*Aviculopecten obliquus*, sp. nov. (Pl. I. fig. 8.)

*Specific Characters.*—Shell small, oblique; body of the valve ovate, acute. The right valve convex. The anterior margin is short and convex. The inferior descends and is broadly convex. The postero-inferior part of the valve produced and bluntly rounded. The line which forms the margin from the umbo to the postero-inferior angle is almost straight, and defines the valve from the posterior ear. The hinge line is straight, long, produced posteriorly into an acute point. The umbones are small, pointed, level with the hinge line, and placed very slightly anterior to the centre of the hinge line. The anterior ear is depressed, rolled, comparatively large and deep, separated from the valve by a fold and notch. The posterior ear is much compressed, triangular, pointed, its margin falcate.

*Interior.*—Not exposed.

*Exterior.*—The right valve is ornamented by many thick, nodulose, radiating ribs, between each pair of which linear plain ribs are intercalated. The anterior ear has a few radiating ribs; the posterior, fine concentric lines of growth.

*Dimensions.*—Pl. I. fig. 8. Specimen No. T4507[B], a right valve, measures: antero-posteriorly, 12 mm.; dorso-ventrally, 12 mm.

*Locality.*—Midlothian, Bilston Burn near Polton, bed 27 to 30 feet above Castlecary Limestone.

*Observations.*—Unfortunately only right valves of this species have been found. The nodular ornament is very well marked. One specimen, which consists of the fossil and its counterpart, shows an almost perfect shell; the other is a cast of the exterior.

The species has somewhat the characters of the ornament of *A. Murchisoni*; the obliquity of the valve and the deep posterior ear are not characteristic of that species. In *A. Murchisoni*, the right valve is flattened, and the ribs are much less nodular than in the left valve.

*Aviculopecten regularis*, sp. nov. (Pl. I. figs. 2, 3.)

*Specific Characters.*—Shell of moderate size, the left valve gibbose, the right flattened. The body of the valve triangular, the lower margin broadly rounded. The hinge line straight, equal in length to the greatest transverse diameter. Umbones small, pointed, subcentral. The ears are depressed, especially the anterior; the posterior has its upper margin produced to a point, and its posterior margin falcate.

*Exterior.*—The right valve has its anterior ear radially ribbed and its posterior almost smooth, but almost obsolete distant radiating lines can be seen with a microscope. The rest of the valve has fine flattened, close radiating ribs, becoming thicker as they approach the margin. The left valve has coarse, raised linear ribs; between each pair, fine secondary ribs appear towards the inferior margin. Concentric lines of growth are visible in the umbonal region. The ears of the left valve are not well seen.

*Dimensions.*—Pl. I. fig. 3. Specimen No. T4514[B] measures: antero-posteriorly, 16 mm.; dorso-ventrally, 13 mm.

*Locality.*—Midlothian, Bilston Burn near Polton, bed 27 to 30 feet above the Castlecary Limestone.

*Observations.*—Two specimens, a right and a left valve, which I think belong to each other, have been obtained, neither of which is, unfortunately, perfect. The marking of the left valve is well preserved. I have been unable to refer the specimens to any described species, and I have been obliged to consider it as a new species.

? *Aviculopecten neglectus*, Geinitz, sp., 1866. (Pl. I. figs. 4–7.)

*Pecten neglectus*, Geinitz, 1866, *Carb. und Dyas in Nebraska*, p. 33, T. ii. fig. 17.
*Aviculopecten neglectus*, Meek, 1867, *Amer. Journ. Sci. and Arts*, vol. xliv., sec. ser., p. 183.
„ „ Meek, 1872, *Fin. Rep. U.S. Geol. Surv. Nebraska*, p. 193, pl. ix. fig. 1, *a*, *b*.
„ „ Meek and Worthen, 1873, *Geol. Surv. Illinois*, vol. v. p. 589, pl. 261, fig. 7.

*Specific Characters.*—Shell small, its body subovate, acute, only moderately gibbose. The margin is regularly rounded below. The hinge line straight, shorter than the greatest transverse diameter. The umbo is small, pointed, not elevated, subcentral. The anterior ear in the right valve is small and flattened, triangular, separated from the body of the valve by a groove and notch. It is ornamented by strong radiating ribs. The posterior ear is triangular, depressed, with fine radiating markings, its margin falcate.

*Exterior.*—The right valve has its body almost smooth, with fine concentric markings. The left valve is almost smooth in its juvenile condition, but becomes

finely radially striate near its lower margin in the more recent part of the valves. Shell very thin.

*Dimensions.*—Specimen No. T4503[B], a right valve, measures: antero-posteriorly, 10 mm.; dorso-ventrally, 10 mm. Pl. I. fig. 5.

*Locality.* — Midlothian, Bilston Burn near Polton, bed 27 to 30 feet above the Castlecary Limestone.

*Observations.*—Several specimens of the right valve of this species, but only two of the left, have been obtained. Comparing the specimens with the figures given by MEEK in the report on Nebraska (*op. supra cit.*), it will be seen that he gives a very perfect figure of the right valve, with which our specimens agree; but it would seem that he copied Geinitz's figure of the left valve, which I have reasons for thinking may have been a right valve with the ears imperfectly exposed, because the left-hand ear in that specimen has a falcate margin and should therefore be the posterior. Amongst the specimens from the Bilston Burn is a left valve (fig. 4, Pl. I.) which shows in its umbonal region a surface free from radiating ribs, but towards the margin ribs gradually arise and become close and numerous. The specimen is a left valve, and I have suspected that it is the left valve of the smooth right valves which agree with the American right valve in every essential character.

In vol. v. of the Geological Survey report on Illinois, WORTHEN gives the figure of the hinge plate, showing a number of parallel cartilage pits, closer on the anterior than on the posterior side, and a central cartilage cavity. If he is correct, the shell cannot be referred to *Aviculopecten*, but will require a new genus to be created for it.

MEEK figures a left valve with radial ribs, from Bed C, Nebraska, in which ? *A. neglectus* occurs, as *A. coxanus*, M. and W. It is possible that this may be the left valve, and that I am dealing with partially decorticated specimens, and am wrong in thinking that the valve was not radially ribbed in the umbonal region.

*Posidoniella lævis*, Brown, sp., 1841. (Pl. I. fig. 15.)

For synonymy, *vide* Hind, Pal. Soc., 1897, *Brit. Carb. Lamell.*, p. 94.

I have referred certain small shells to this species, which is extremely common in the shales of the Millstone Grit in the Midlands of England. The specimens are not good, and are small and crushed, but on the whole fairly distinctive of the species; it seems to have been very rare in Scotch localities, and dwarfed.

*Myalina Verneuillii*, M'Coy, sp., 1854. (Pl. I. fig. 16.)

For synonymy, *vide* Hind, Pal. Soc., 1897, *Brit. Carb. Lamell.*, p. 115.

I have referred some fragments of a large shell with a broad alate posterior end to this species, but they are also very suggestive of *M. redesdalensis*. Some smaller specimens one can positively refer to M'COY's species, which has been obtained in beds of the Millstone Grit series near Marsden, on Pule Hill, Yorkshire. *M. Flemingi* occurs

with this species at Pule Hill, and I have recognised that species in a collection from Garngad Road made by Mr J. NEILSON of Glasgow.

*Locality.*—9 to 10 feet above the Castlecary Limestone, Torwood, Stirlingshire; Greenfoot Quarry, near Gain Farm, Dumbartonshire; and Bilston Burn, Midlothian.

*Nucula gibbosa*, Flem., *vide* Hind, Pal. Soc., 1897, *Brit. Carb. Lamell.*, p. 178. Pl. I. figs. 18, 19.
*Nuculana attenuata*, Flem., sp., *vide* Hind, Pal. Soc., 1897, *Brit. Carb. Lamell.*, p. 195.
*Ctenodonta lævirostris*, Portl., sp., *vide* Hind, Pal. Soc., *Brit. Carb. Lamell.*, pp. 183, 210; pt. ii. p. 164.

These three species occur together at many horizons in the Carboniferous sequence, from the Calciferous Sandstone series to the Coal Measures.

It is interesting to note that each genus is represented in the Coal Measures of North America by a closely allied species—*Nuculana* (*Yoldia*) *subsulcata*, *Nuculana bellistriata*, *Ctenodonta* (*allorisma*) *reflexa*.

### *Nuculana lævistriata*, Meek and Worthen, sp. (Pl. I. fig. 17.)

For synonymy, *vide* Hind, Pal. Soc., 1897, *Brit. Carb. Lamell.*, p. 205.

This species is found in the St Louis group of the Lower Carboniferous beds of North America, but in Scotland it is very common at Waulkmill Glen in the Upper Limestone series. It seems to be rare in the Millstone Grit localities.

*Locality.*—River Avon, between the outcrop of the Castlecary Limestone and the Railway Viaduct.

### *Modiola subelliptica*, Meek, 1867. (Pl. I. fig. 20.)

*Clidophorus* (*Pleurophorus*) *occidentalis*, Geinitz, 1866, *Carb. und Dyas in Nebraska*, p. 23, pl. ii. fig. 6.
*Pleurophorus subellipticus*, Meek, 1867, *Amer. Journ. Sci. and Arts.*, vol. xliv., new ser., p. 181.
*Modiola ? subelliptica*, Meek, *Fin. Rep. U.S. Geol. Surv. Nebraska*, 1872, p. 211, pl. x. fig. 5.

*Specific Characters.*—Shell small, transversely triangular, comparatively convex. The anterior end is small, narrow and rounded. The posterior end comprises about four-fifths of the valve. The anterior border is narrow and elliptical. The lower border descends slowly, meeting the posterior with a broad, blunt curve. The posterior margin is very oblique and somewhat convex in contour, making an obtuse angle above with the hinge line. The latter straight, equalling in length almost half the antero-posterior diameter. The umbones are small, placed far forward, but not terminal. Well marked, rounded, oblique swelling, which gradually becomes obsolete, extends from the umbo to the postero-inferior angle. Above the ridge the dorsal slope is rapidly compressed, and below it there is a well-marked byssal compression.

*Interior.*—Not exposed.

*Exterior.*—The surface is adorned by close, fine, concentric lines of growth.

*Dimensions.*—Specimen No. T1712[B] measures: antero-posteriorly, 7 mm.; dorso-ventrally, 3 mm.

*Locality.*—Torwood Glen, Stirlingshire, 8 to 10 feet above the Castlecary Limestone.

*Observations.*—A single specimen of this shell has occurred, a left valve, and I have referred it to MEEK's species. The American shell reaches about 25 mm. in its transverse diameter, and therefore we must regard the Scotch specimen as immature.

*Grammatodon tenuistriata*, Meek and Worthen, sp., 1872. (Pl. I. fig. 21.)

*Macrodon tenuistriata*, Meek and Worthen, 1867, *Proc. Chicago Acad. Sci.*, i. p. 17.
*Arca striata*, Geinitz, 1866, *Carb. und Dyas in Nebraska*, p. 20, pl. i. fig. 32.
*Macrodon tenuistriata*, Meek and Hayden, 1872, *Fin. Rep. U.S. Geol. Surv. Nebraska*, p. 207, pl. x. fig. 20, *a*, *b*.
*Parallelodon tenuistriata*, Bolton, 1907, *Q. J. Geol. Soc.*, p. 460, pl. xxx. fig. 12.

*Specific Characters.*—Shell small; somewhat transverely oblong, gibbose. The anterior end is bluntly rounded, the antero-superior angle well marked. The inferior and superior borders sub-parallel. The hinge line straight, the lower margin very slightly convex, deeply indented above its centre for the byssus. The posterior end obliquely truncate, almost straight. The umbones are turned, raised, incurved, and pointed, placed at the junction of the anterior and middle thirds of the hinge line. The body of the valve is convex, deeply indented towards the margin of the byssal sulcus. The dorsal slope is as much compressed as to be concave. It is separated from the rest of the valve by a well-marked angular ridge, which extends from the umbo to the postero-inferior angle.

*Interior.*—Normal.

*Exterior.*—The general surface of the valve is ornamented by the decussation of the concentric lines of growth by close radiating lines. The latter become so much stronger on the dorsal slope as to form strong radiating ridges.

*Dimensions.*—Pl. I. fig. 21. Specimen No. T1812[B] measures: antero-posteriorly, 12 mm.; dorso-ventrally, 7 mm.

*Locality.*—Linlithgow, right bank of river Avon between the Railway Viaduct and the outcrop of the Castlecary Limestone, and in the Bilston Burn section, Midlothian.

*Observations.*—*G. tenuistriata*, M. and H., is closely allied to *G. semicostatus*, M'Coy, of which it is probably a mutation. It is, however, much less transverse, deeper and more gibbose.

Only two examples of the species are in the collection. *G. semicostatus* is very abundant at a horizon a very little below that in which *G. tenuistriata* occurs, namely, below the Linn Spout Limestone. Mr H. WOODS has shown (*Ann. Mag. Nat. Hist.*, 1899, ser. 7, vol. iii. p. 47) that the name *Grammatodon*, Meek and Hayden, is prior to *Parallelodon* of the same authors, and must replace it. It appears that *Macrodon* of Lycett, founded for a Jurassic shell, was occupied for a genus of fishes and cannot therefore be used, and that there is no essential difference in the type of the hinge of the Carboniferous and Jurassic forms.

*Protoschizodus curtus*, Meek and Worthen, sp., 1866. (Pl. I. figs. 22, 23.)

*Schizodus curtus*, Meek, 1866, *Proc. Chicago Acad. Sci.*, vol. i. p. 18.
„ *rossicus*, Geinitz, 1866, *Carb. und Dyas in Nebraska*, p. 18, Tab. i. fig. 28.
„ *curtus*, Meek and Worthen, 1872, *Fin. Rep. U.S. Geol. Surv. Nebraska*, p. 208, pl. x. fig. 13, *a*, *b*, *c*, *d*?, *e*.

*Specific Characters.*—Shell triangularly suborbicular, moderately gibbose, almost equilateral. The anterior margin almost straight above, oblique, bluntly rounded below in the inferior border, which is broadly convex. The posterior margin is narrowed, straight, obliquely truncate. Hinge line arched short. The umbones are well marked. raised, pointed, moderately gibbose, and central. Passing from the umbo obliquely to the postero-inferior angle is a well-marked angular ridge which separates the convex portion of the valve from the rapidly compressed dorsal slope.

*Interior.*—Muscle scars normal.

*Exterior.*—The surface is almost smooth, but obscure concentric lines of growth are apparent near the lower margin of the valve.

*Dimensions.* — Pl. I. fig. 22. Specimen No. T1982[B], a right valve, measures: antero-posteriorly, 16 mm.; dorso-ventrally, 15 mm.

*Localities.*—Stirlingshire, Torwood Glen, $2\frac{1}{2}$ miles N.W. of Larbert, 9 to 10 feet above Castlecary Limestone; Linlithgow, river Avon, right bank, between Railway Viaduct and outcrop of Castlecary Limestone; Greenfoot Moulding Sand Quarry, near Gain Farm, Dumbartonshire.

*Observations.—Protoschizodus curtus* resembles very closely *P. subæqualis*, de Kon, from the upper beds of Carboniferous Limestone of Thorpe Cloud, Upper Dibunophyllum zone; but the Scotch examples are less gibbose, more triangular, and have a more oblique, straighter anterior border. The umbones are more subcentral and more elevated. Meek and Worthen recognised the close resemblance between the American shell and *Schizodus rotundatus* of the Permian. I think they were right in separating the species for several reasons. In the first place, *S. rotundatus* was established on a single example, and I believe has not been figured since King's monograph was published in 1841; and we learn from the note on the explanation of the plate that "the figure makes the specimen more perfect than it really is." It is important, however, to note the close relationship between the three forms.

I have referred the species to *Protoschizodus* on account of its general shape and contour. This species is fairly common in at least two of the Scotch localities.

*Schizodus Wheeleri*, Swallow, sp., 1862. (Pl. I. figs. 22–28.)

*Cypricardia ? Wheeleri*, Swallow, 1862, *Trans. St Louis Acad.*, vol. i. p. 96.
*Schizodus obscurus*, Geinitz, 1866, *Carb. und Dyas in Nebraska*, p. 20, Tab. i. figs. 30, 31.
„ *Wheeleri*, Meek and Hayden, *Fin. Rep. U.S. Geol. Surv. Nebraska*, p. 209, pl. x. fig. *a*, *b*, *c*, *d*, (*e*, *f*?).

*Specific Characters.*—Shell moderately gibbose; dorsal slope much compressed,

transversely subovate. The anterior margin is deep and regularly rounded, passing with uninterrupted curve into the lower border, which is also convex, but the segment of a larger curve than the anterior margin. The posterior end is narrowed, obliquely truncate, almost straight. The postero-inferior angle acute, the postero-superior obtuse. The hinge line is short, very slightly arcuate. The umbones are large, gibbose, elevated above the margin, incurved, and subcentral. Passing obliquely from the umbo to the postero-inferior angle is a well-marked subangular ridge which separates the dorsal slope from the convex portion of the valve.

*Interior.*—The hinge plate is normal.

*Exterior.*—The surface is ornamented in front by regular lines of growth, which become less marked over the posterior portion of the valve.

*Dimensions.*—Pl. I. fig. 24. Specimen No. T1865[B], a right valve, measures: antero-posteriorly, 26 mm.; dorso-ventrally, 20 mm.

*Locality.*—Stirlingshire, Torwood Glen, 2½ miles N.W. of Larbert, in a bed 9 to 10 feet above Castlecary Limestone; Linlithgow, river Avon, about 100 yards below the Mill, right bank, at the bend where stream takes a northerly direction, about ⅛ mile N. of Avonbank.

*Observations.*—This species is represented by a larger number of individuals than any other in the collection. It is seen that amongst them there is a fair amount of variation. The same thing is observed in the figures of the American types figured by Meek. We can even match the larger form (fig. 1, *f*), doubtfully referred to the species by Meek, amongst the Scotch specimens. There is certainly a much closer resemblance to the Permian *Schizodus obscurus* than to any other British species; but it would seem to connect *S. axiniformis*, which ranges from the upper part of the Carboniferous Limestone series (Redesdale ironstone) to the Coal Measures (Coalbrookdale), with the later form. From the study of a series it would appear that, with age, the angularity of the oblique ridge tends to disappear, and the posterior end becomes produced.

? *Anthracomya truncata*, sp. nov. (Pl. I. figs. 29, 30.)

*Specific Characters.* — Shell small, triangular, compressed, rapidly expanded posteriorly, greatest vertical and horizontal diameter equal. The anterior end is short, its margin rounded. The inferior border descends rapidly, joining the long, straight, obliquely truncate posterior border by an elliptical curve. The hinge line is straight; the longest transverse diameter of the valve forms a well-marked obtuse angle with the posterior border. The umbones are small, slightly elevated and swollen, placed at the junction of the anterior and middle thirds of the hinge line. The valve is obliquely swollen, forming a well-defined but gradually diminishing rounded ridge passing from the umbo towards the postero-inferior angle.

*Interior.*—Not exposed.

*Exterior.*—The surface is almost smooth, but under the lens close, fine concentric lines of growth, with here and there a stronger line, the latter being more conspicuous in the umbonal region. The periostracum apparently thick.

*Dimensions.*—Specimen No. T2743[B] measures: antero-posteriorly, 5 mm.; dorso-ventrally, 5 mm.

*Locality.*—In black micaceous shale in drain in bottom of Greenfoot Quarry, near Gain Farm, 3 miles N. of Coatbridge. (Position of Castlecary Limestone.)

*Observations.*—Two small pieces of black shale labelled T2742[B] and T2743[B] are covered with black shiny shells and fragments which are new to me. The shells are probably somewhat crushed, but they have the general shape and contour of *Anthracomya*, to which genus I am led to refer them. They differ from *A. valenciensis* in being more triangular and less globular, and in having a well-marked oblique rounded ridge and a very rapidly expanded posterior extremity. The comparatively thick periostracum is a fact in favour of affinity of this small shell to *Anthracomya*. One slab shows four fairly well-preserved specimens of left valves, the other a practically perfect specimen of the right valve.

For its size this species is more rapidly expanded posteriorly than any of its genus, and foreshadows the character of the large *Anthracomya Adamsii* and its variety *A. Adamsii*, var. *expansa*, of the middle portion of the Coal Measures of England. A slab labelled T2156[B], from a dark shale on top of a 2-inch coal resting on the Glenboig Fireclay Seam, Fireclay Mine, Glenboig.

*Edmondia excentrica*, sp. nov. (Pl. II. figs. 31, 32.)

*Specific Characters.*—Shell small, only moderately gibbose, subrotundate, quadrate, moderately transverse, inequilateral. The anterior end is bluntly rounded, the inferior margin broadly convex, the posterior blunt, convex, somewhat broader than the anterior. The hinge line arcuate. The umbones are small, incurved, placed in front of the middle portion of the valve.

*Exterior.*—The surface is ornamented with concentric lines and rugæ of growth, and are arranged somewhat obliquely to the long axis of the valve.

*Dimensions.*—Pl. II. fig. 32. Specimen No. T1945[B] measures: antero-posteriorly, 18 mm.; dorso-ventrally, 12 mm.

*Localities.*—Stirlingshire, Torwood Glen, $2\frac{1}{2}$ miles N.W. of Larbert, 9 feet above Castlecary Limestone; river Avon, $\frac{1}{4}$ mile S.E. of Inveravon, Linlithgowshire; Glencryan, $1\frac{3}{4}$ miles S.S.E. of Cumbernauld, Dumbartonshire.

*Observations.*—A typical *Edmondia*, with an affinity to *E. senilis*, but of quite a different habit of growth, hence its creation into a species.

The *Edmondia reflexa* of Meek, from the Coal Measures of North America, is a more transverse shell with more regular and less rugose markings.

*Edmondia Lyellii*, Hind, 1899. (Pl. II. fig. 35.)

For synonymy, *vide* Hind, Pal. Soc., 1899, *Brit. Carb. Lamell.*, vol. i. p. 300.

A fragment of what I take to be the right valve of this species was obtained at Torwood Glen, Stirlingshire.

*Edmondia sulcata*, Phillips, sp. (Pl. II. fig. 33.)

For synonymy, *vide* Hind, Pal. Soc., 1899, *Brit. Carb. Lamell.*, p. 318.

A single specimen of this shell has been obtained from the Millstone Grit horizon at river Avon, between the Railway Viaduct and the Castlecary Limestone, Linlithgow. The specimen, though crushed, is well preserved, and not to be mistaken. It is a right valve, and shows in places the radiating lines of tubercles with which the posterior portion of the valve was covered. Another better specimen was got on the same horizon at Torwood Glen, Stirlingshire. Other examples were got at Gain Quarry, Dumbartonshire. The figured example, No. T1858[B], is from the river Avon, on west side of the Railway Viaduct, 100 yards below the Mill.

*Sanguinolites occidentalis*, Meek and Hayden, sp., 1858. (Pl. II. figs. 36–38.)

*Pleurophorus occidentalis*, Meek and Hayden, 1858, *Trans. Albany Instit.*, iv.
" " Meek and Hayden, 1864, *Pal. Upper Missouri*, p. 35, pl. i. fig. 11*a*.
*Clidophorus Pallasi*, Geinitz pars., 1866, *Carb. und Dyas in Nebraska*, p. 23, pl. ii. fig. 3.
*Pleurophorus occidentalis*, Meek and Hayden, 1872, *Fin. Rep. U.S. Geol. Surv. Nebraska*, p. 212, pl. x. fig. 12.

*Specific Characters.*—Shell ovate, oblong, broader behind than in front, obliquely gibbose. The anterior end is short, its margin rounded. The upper and lower borders subparallel. The posterior margin obliquely subtruncate, junction of lower and posterior borders bluntly rounded. The postero-superior angle well marked, obtuse. The umbones are small, pointed, directed forwards, only very slightly raised above the hinge line and placed far forwards. Passing obliquely from the umbo to the postero-inferior angle is a bluntly rounded ridge which separates a broad and compressed dorsal slope from the narrow and somewhat compressed body of the valve. The edge of the upper margin is thickened posteriorly, and forms a ridge; between it and the oblique ridge are two well-marked oblique lines which extend to the posterior border. Escutcheon well marked.

*Interior.*—Normal. Hinge plate apparently edentulous.

*Exterior.*—The surface is ornamented by somewhat irregular rugose but fine lines of growth, which become much less obvious on the dorsal slope.

*Dimensions.*—Pl. II. fig. 37. Specimen No. T2216[B], a left valve, measures: antero-posteriorly, 20 mm.; dorso-ventrally, 9 mm.

*Localities.*—Linlithgow, river Avon, right bank, between Railway Viaduct and the outcrop of the Castlecary Limestone; Stirlingshire, Torwood Glen, 2½ miles N.W. of

Larbert, 9 to 10 feet above the Castlecary Limestone. Specimen No. T2216[B] is from the pit shaft of Steens Fireclay Works, ¾ mile E. of Castlecary Railway Station; Bilston Burn section, Midlothian.

*Observations.*—I have referred this species to the genus *Sanguinolites* rather than *Pleurophorus*, as there are no signs of the characteristic cardinal teeth of the latter genus. I think there can be little doubt of the relation of the shell to the American species. I have compared the suite of specimens with *Sanguinolites ovalis*, Hind, but the two radiating ridges on the dorsal slope at once separate it from this species. The figure of the specimens from Nebraska (*op. supra cit.*) is from the cast of an interior, copied from GEINITZ's work. It is shown to have three curious curved lines passing from the front of the umbo to the lower border. I cannot think that these are natural, and I have never seen any similar structure in a sanguinolitiform shell. The species is represented in the collection by seven examples, amongst which is a fairly well-preserved testiferous example, and a cast of the left valve (Pl. II. fig. 38).

This species belongs to the group of *Sanguinolites tricostatus*, but it is considerably less transverse than that species. Externally there is a strong resemblance to the *Pleurophorus elegans* of the Permian.

### ? *Allorisma reflexa*, Meek. (Pl. II. fig. 39.)

*Allorisma* (*Sedgwickia*) *reflexa*, Meek, *Fin. Rep. U.S. Geol. Surv. Nebraska*, p. 217, pl. iv. fig. 15.

A small slab, No. T2177[B], is covered with a very strongly marked shell, of which, however, no single specimen is perfect. I refer it provisionally to *Allorisma reflexa*, Meek, with the description of which it seems to agree.

I have doubts whether MEEK's generic diagnosis is correct, as the shell has not the general shape usual in *Allorisma*.

The dimensions of one of the Scotch shells, a right valve, are: antero-posteriorly, 20 mm.; dorso-ventrally, 8 mm.

*Locality.*—Glencryan, 1¾ mile S.S.E. of Cumbernauld, Dumbartonshire, 10 to 20 yards down stream from the fault, and on the under side of the waterfall.

### *Tellinomorpha Hindii*, Bolton, 1907. (Pl. II. figs. 40–42.)

*Tellinomorpha Hindii*, Bolton, 1907, *Q. Journ. Geol. Soc.*, vol. lxiii. p. 460, pl. xxx. fig 8, *a*, *b*.

*Specific Characters.*—Shell somewhat transverse, gibbose, with a much-compressed dorsal slope, inequilateral. The anterior end is short and narrowed, its margin rounded. The inferior border is gently curved, and meeting the posterior at a well-marked angle. The posterior border is obliquely truncate, almost straight, moderately short, making an obtuse angle with the hinge line, the latter straight. The umbones are gibbose, elevated, incurved, and situated in front of the middle of the valve. Lunule large and broad. Escutcheon narrow, but well marked. From the umbo to the postero-inferior

angle of the valve extends a blunt subangular ridge, which divides the convex portion of the valve from the concavity of the dorsal slope.

*Interior.*—Not known.

*Exterior.*—The surface of the valve is ornamented with numerous concentric, irregular rugæ and lines of growth, which tend to become obsolete on the dorsal slope.

*Dimensions.*—Specimen No. T2450[B] measures: antero-posteriorly, 11 mm.; dorso-ventrally, 7 mm.; gibbosity of valve, 3 mm.

*Localities.*—Dumbartonshire, Greenfoot Moulding Sand Quarry, near Gain Farm, 3 miles N. of Coatbridge; Stirlingshire, Torwood Glen, 2½ miles N.W. of Larbert, 9 to 10 feet above the Castlecary Limestone; Linlithgow, river Avon, 35 to 40 feet above the Castlecary Limestone.

*Observations.*—This species is represented in the collection by a very large number of individuals, by far the largest number of which came from the Gain Quarry. The specimens occur in ferruginous nodules which lie above the Upper Cementstone. The shell has a distinctive appearance, being very rugose for so small a shell. The narrowed truncate posterior end and well-compressed dorsal slope, comparatively large lunule and escutcheon, indicate fairly conclusively, even in the absence of details of the hinge and interior, the generic affinity of the species. The genus *Tellinomya* is represented in the Coal Measures of North America by *Tellinomya* (*Allorisma, Sedgwickia*) *granosa* of Shumard, and probably the *Allorisma* (*Sedgwickia*) *subelegans* of Meek. The former species is very much larger than the one just described, but the latter agrees with it very well as to size. From the figure and descriptions, the ornament appears to be regular, and the shell is described by Meek as rather compressed, a character which does not suit the Scotch species. With a strong lens, I think the remains of the characteristic tubercles with which the surface of shells belonging to the genus are covered are to be seen. Since writing the description I recognised the species in a collection made by Mr H. Bolton from the base of the Coal Measures of Bristol, who has published a description and figures (*op. supra cit.*). He appears doubtful of the genus, and suggests *Parallelodon*, but I cannot accept this view. The small amount of the hinge plate that I have seen has none of the characters of that genus. The antero-superior angle of the shell is quite unlike the arciform type, and is rounded, and not square and compressed.

*Solenomorpha cylindrica*, sp. nov. (Pl. II. figs. 43, 44.)

*Specific Characters.*—Shell small, narrow, transverse, very inequilateral, dorsal and ventral margins subparallel. The anterior end is comparatively elongate, narrow; its anterior superior angle almost pointed, the border elliptically curved. The posterior end is truncate, blunt, not much narrowed, making a rounded angle below with the inferior margin, and a slightly obtuse angle with the hinge line above. The umbones are compressed, elongate, and not elevated. The dorsal slope is slightly compressed,

bounded below by an obscure ridge which continues from the umbo to the postero-inferior angle.

*Interior.*—Not observed.

*Exterior.*—The surface appears to be almost smooth.

*Dimensions.*—Specimen No. 2441, a left valve, measures: antero-posteriorly, 9 mm.; dorso-ventrally, 3 mm. (Pl. II. fig. 44.)

*Locality.*—Dumbartonshire, Greenfoot Moulding Sand Quarry, near Gain Farm, 3 miles N. of Coatbridge.

*Observations.*—I have referred these specimens to the genus *Solenomorpha* on account of the elongate form and the peculiar elongated anterior end and the narrow compressed umbones. The posterior end is broader than is usual in species of this genus. The American Coal Measures species (*Solenopsis*) *Solenomorpha solenoides* of Geinitz has the normal condition of a narrowed posterior end and a somewhat less prolonged anterior end.

*Solenomya brevis*, sp. nov. (Pl. II. figs. 45–47.)

*Specific Characters.*—Shell small, transverse, tumid, lenticular, narrowed at both extremities, very inequilateral. The anterior end long, its margin elliptical. The inferior margin is convex; the posterior truncate, rounded. The hinge line is gently arched. The umbones are inconspicuous, elongate and adpressed, placed far back so that the posterior end is short and rapidly compressed, especially above.

*Interior.*—Normal.

*Exterior.*—Almost smooth, with very fine concentric striæ of growth.

*Dimensions.*—Pl. II. fig. 46. Specimen No. T2718[B] measures: antero-posteriorly, 16 mm.; dorso-ventrally, 8 mm.; gibbosity of valve, 3 mm.

*Locality.*—Dumbartonshire, Greenfoot Moulding Sand Quarry, near Gain Farm, 3 miles N. of Coatbridge.

*Observations.*—This species belongs to the group of *Solenomya*, which does not possess radiating ribs passing across the middle part of the valves. The absence of these ribs and the peculiar boat-shaped valve at once distinguish the species from *S. cylindrica*, which occurs at the same horizon. Its nearest congener is *S. excisa*, but this is a much larger and more transverse shell.

*Solenomya cylindrica*, sp. nov. (Pl. II. figs. 60, 61.)

*Specific Characters.*—Shell small, narrow, transversely elongate, gibbose, very inequilateral. Anterior end long, its margin bluntly rounded. The hinge line and inferior border are almost parallel. The posterior end narrower than the rest of the valve, its margin elliptical. The umbones are small, not elevated, excavated posteriorly, and placed in the posterior fourth of the hinge line.

*Interior.*—Normal.

*Exterior.*—The surface is almost smooth, but with the microscope fine concentric lines of growth are visible. The valve is crossed by several radiating obscure flattened ribs, apparent even in casts.

*Dimensions.*—Pl. II. fig. 60. Specimen No. T1984[B], a right valve, measures: antero-posteriorly, 19 mm; dorso-ventrally, 7 mm.

*Locality.*—Dumbartonshire, Greenfoot Moulding Sand Quarry, near Gain Farm, 3 miles N. of Coatbridge.

*Observations.*—The species differs from *S. costellata*, M'Coy, being much more gibbose and comparatively more transverse and much narrower. The radiating ribs are much less obvious. Three specimens are present in the collection. It is possible that the species is a mutation of *S. costellata*, for there is no doubt that the two forms are closely related, but the differences seem to me to be sufficiently strong to be indicated by a new term. Apparently the genus is represented in the Coal Measures of Illinois, for the name of the genus occurs twice in the list on page 126 of the *Final Report of U.S. Geological Survey of Nebraska*, but no mention is made of any species in the text.

## Genus, *Prothyris*, Meek, 1869.

*Prothyris*, Meek, 1869, *Proc. Acad. Nat. Sci. Philad.*, p. 172.
„ Meek, 1871, *Amer. Journ. Conch.*, vol. vii. p. 5, pl. i. fig. 3.
„ Meek, 1872, *Fin. Rep. U.S. Geol. Surv. Nebraska*, p. 223, pl. x. fig. 9, *a*, *b*.
„ Hall, 1885, *Geol. Surv. N. York*, Pal., vol. v. pt. i., Lamellibr. ii., p. xl.
„ Miller, 1889, *N. Amer. Geol. and Pal.*, p. 504.
„ Whidborne, Pal. Soc., 1890, *Devonian Fauna*, p. 86.

*Generic Characters.*—Shell compressed, narrow, transversely elongate, with a small ear-like process from the antero-posterior angle, separated from the shell by an angular ridge, probably for the byssus. Dorsal slope compressed.

*Observations.*—The genus is easily recognised by the peculiar-shaped process at its anterior end. The genus was founded by MEEK for a shell from the Coal Measures of Nebraska. The original account (*op. supra cit.*) was very meagre, and unaccompanied by any figures. However, in 1871 he gave figures, and, I presume, a more elaborate description, and again in 1872 (*op. supra cit.*). In North America the genus was subsequently found to occur as low as the Hamilton series, where it is represented by two species. Two others are known from the Chemnung and one from the Waverley Sandstone. In England, the Rev. G. F. WHIDBORNE has described three species from the Marwood and Pilton beds of North Devon.

The internal characters are not known. I think it probable that the ear-shaped process contained the anterior abductor muscle, and the hollow separating it from the rest of the shell was for a byssus. Fischer doubtfully places the genus in the *Solenidæ*. Apart from the anterior ear-like process, the shell has a strong resemblance to some species of *Sanguinolites*.

*Prothyris elegans*, Meek, 1871. (Pl. II. figs. 48–50.)

*Prothyris elegans*, Meek, 1871, *Amer. Journ. Conch.*, vol. vii. p. 5, pl. i. fig. 3.
" " Meek and Hayden, 1872, *Fin. Rep. U.S. Geol. Surv. Nebraska*, p. 223, pl. x. fig. 9, *a*, *b*.

*Specific Characters.*—Shell moderately compressed, transversely oblong, dorsal and ventral margins straight and parallel. The anterior superior angle is expanded into a small, pear-shaped process, not extending below the upper third of the border, the broad end pointing downwards and forwards. This process is separated from the rest of the shell by a raised ridge, which is continued below as the anterior margin, which is bluntly rounded. The posterior margin is obliquely subtruncate and almost straight. The postero-inferior angle bluntly rounded; the postero-superior angle almost obtuse. The umbones very small, depressed, and placed very far forwards: they would be terminal were it not for the ear-like expansion. The upper margin of each valve is compressed by a shallow groove immediately below the hinge line. Another groove passes obliquely from the region of the umbo towards the posterior margin some little distance below. Below these two grooves is a rounded ridge, which becomes broader as it approaches the posterior end. Below this the valve is very gently convex.

*Interior.*—Unknown.

*Exterior.*—That portion of the valve near the upper margin and the dorsal slope is almost smooth. Nearer the ventral border there are fine close lines of growth, parallel with the margins.

*Dimensions.*—Pl. II. fig. 48. Specimen No. T2505[B], a right valve, measures: antero-posteriorly, 17 mm.; dorso-ventrally, 5 mm.

*Locality.*—Dumbartonshire, Greenfoot Moulding Sand Quarry, near Gain Farm, 3 miles N. of Coatbridge. Horizon: Millstone Grit of Scotland.

*Observations.*—Although the Rev. G. F. Whidborne has recorded three species of the genus *Prothyris* from the Devonian rocks of England, it has not been previously found in the Carboniferous beds of Great Britain (*vide ante*, p. 332). The type of the genus is *Prothyris elegans*, a species which occurs in the Coal Measures of Nebraska and Illinois. I have been unable to note any specific difference between the American and Scotch specimens after careful comparison with a series from Nebraska in my collection. Many examples have been obtained by Mr. Tait from the locality named above—fortunately right and left valves. In some the ear-like process which is characteristic of the genus has broken away. The left valve is represented by the fossil and its counterpart, the latter showing the ear very perfectly. I have seen other examples in the possession of Mr. J. Smith of Dalry.

GASTEROPODA.

*Loxonema nanum*, de Koninck, 1881. (Pl. II. fig. 51.)

*Loxonema nanum*, de Koninck, 1881, *Ann. Mus. Roy. d'Hist. Belg.*, tome vi. p. 50, pl. iv. figs. 45, 46.

*Specific Characters.*—Shell very small, elongate; spire consisting of 8 to 9 whorls.

Regularly convex. Suture lines well depressed; often a slight ridge immediately above the suture.

*Dimensions.*—Specimen No. T2182[B] measures: height, 4·5 mm.; breadth, 1·5 mm.

*Localities.*—Moulding Sand Quarry, Garngad Road, Glasgow; Dumbartonshire, Greenfoot Moulding Sand Quarry, near Gain Farm, 3 miles N. of Coatbridge.

*Observations.*—Two specimens of this minute shell have been obtained. It is almost characterless, and I refer it on this account to the very small shell named by DE KONINCK *L. nanum.*

*Naticopsis brevispira*, de Ryckholt, sp. (Pl. II. figs. 52, 53.)

I described this species as occurring in a marine band below the Gin Mine Coal of the North Staffordshire coalfield (*Q. J. Geol. Soc.*, vol. lxi. p. 533, pl. xxxv. fig. 10). A single specimen has been obtained from Torwood Glen, Stirlingshire.

*Macrocheilina*, sp. (Pl. II. fig. 59.)

Fragments of a small elongate shell with a spire of five whorls have been obtained, but it is impossible to determine the species. The height is 4·5 mm. The specimen is numbered T1929[B].

*Locality.*—Linlithgowshire; river Avon, W. of the Railway Viaduct, about 100 yards below the Mill and $\frac{1}{8}$ mile N. of Avonbank.

*Ptychomphalus Marcouianus*, Geinitz, sp., 1866. (Pl. II. fig. 55.)

*Pleurotomaria Marcouiana*, Geinitz, 1866, *Carb. und Dyas in Nebraska*, 1866, p. 10, Tab. i. fig. 10.
„ „ Meek and Hayden, 1872, *Fin. Rep. U.S. Geol. Surv. Nebraska*, p. 223, pl. xi. fig. 8.

*Specific Characters.*—Shell small, cone rapidly expanding, spire of 5 to 6 whorls, of which the larger comprises nearly the whole of the shell. The upper portion of the whorl is convex, and in the last whorl projects beyond the two keels of the band of the sinus, so that the latter is finally not marginal. It is ornamented with regular close-set spiral ridges. The portion of the whorl above the band of the sinus (*i.e.* nearer the apex) is flattened, and in the early whorls obliterates the sinus. The ornament consists of spiral bands which are moniliform internally, the points becoming small in each successive row till they become obsolete.

*Dimensions.*—Pl. II. fig. 55. Specimen No. T1779[B] measures: height, 6 mm.; breadth, 7 mm.

*Localities.*—Stirlingshire, Torwood Glen, $2\frac{1}{2}$ miles N.W. of Larbert; Dumbartonshire, Greenfoot Quarry, near Gain Farm, 3 miles N. of Coatbridge.

*Observations.*—I have referred these specimens to GEINITZ's species, trusting to the figures in his and MEEK's works. I have been fortunate enough to obtain for study a very

beautifully preserved example which shows the character of the ornament very perfectly. I can find no figure of any British Carboniferous shell which in any way agrees.

### *Entalis Meekianum*, Geinitz, sp., 1866. (Pl. II. fig. 54.)

*Dentalium Meekianum*, Geinitz, 1866, *Carb. und Dyas in Nebraska*, p. 13, Tab. i. fig. 20.
" " Meek and Hayden, 1872, *Fin. Rep. U.S. Geol. Surv. Nebraska*, p. 224, pl. xi. fig. 16, *a*, *b*.

*Specific Characters.*—Shell a conical tube with a gentle curvature; aperture circular. Lines of growth fine, with irregular deeper sulci.

*Locality.*—Stirlingshire, Torwood Glen, $2\frac{1}{2}$ miles N.W. of Larbert. T1765[B].

*Observations.*—A single specimen of this shell has occurred. The exterior is not well preserved, but seems to be smooth. It may be decorticated, however. *Dentalium Meekianum*, Geinitz, from the Coal Measures of Nebraska, is said to have fine moderately distinct lines of growth passing very obliquely round the shell, with here and there a deeper sulcus. Of this character I can see no trace on the Scotch specimen.

A species of the genus is not uncommon in the marine beds of Congleton Edge, 300 feet below the third grit. It is much larger than the Scotch specimen, but of course this is not of specific value, and it may be said that only the narrow terminal portion of the latter is preserved. The Congleton Edge specimen has no longitudinal striæ, but has almost concentric lines of growth with irregular deeper sulci in places, thus corresponding to MEEK's description, to which I have alluded above. MEEK draws attention to the fact that GEINITZ represented the lines of growth in his figures as if they were spiral—a fact which he states to be incorrect. I have followed DE KONINCK in using the generic name of *Entalis*, this genus possessing a slit on the dorsal surface of the posterior or narrow end which is absent in *Dentalium*.

### *Euphemus d'Orbignyi*, Port., sp. (Pl. II. figs. 57, 58.)

*Bellerophon d'Orbignyi*, Portlock, 1843, *Rep. Geol. Londonderry*, p. 401, pl. xxix. fig. 12.
? *Bellerophon carbonarius*, Cox, 1857, *Kentucky Geol. Rep.*, vol. iii. p. 562.
" " Geinitz, 1866, *Carb. und Dyas in Nebraska*, p. 6, Tab. i. fig. 8.
" " Meek and Hayden, 1872, *Fin. Rep. U.S. Geol. Surv. Nebraska*, p. 224, pl. iv. fig. 16; pl. xi. fig. 11, *a*, *b*, *c*.
*Euphemus d'Orbignyi*, de Koninck, 1833, *Ann. Mus. Roy. d'Hist. Nat. Belg.*, tome viii. p. 156, pl. xlii. bis, fig. 5; pl. xliii. figs. 9–12; pl. lxii. figs. 10–12.

*Specific Characters.*—Shell gibbose, umbilicus small, sides compressed. Aperture, transverse subtruncate. The surface is ornamented by about twenty-four spiral ridges separated by concave spiral sulci, which become obsolete over the greater portion of the terminal whorl, and are closer together on the side of the umbilical slope,

*Localities.*—Stirlingshire, Torwood Glen, $2\frac{1}{2}$ miles N.W. of Larbert; Linlithgowshire, river Avon; Midlothian, Bilston Burn section.

*Dimensions.*—Pl. II. fig. 57. Specimen No. T1756[B] measures: height, 16 mm.; transversely, 16 mm.

*Observations.*—Portlock states that he described his species from a single example, which he stated was obtained from Shale in Tyrone. De Koninck referred several specimens from the Carboniferous Limestone of Visé to this species, and gave numerous figures. I am able to detect no specific difference between the descriptions and figures of *Bellerophon carbonarius*, Cox, from the Coal Measures of Nebraska, and the Scotch examples, and have come to the conclusion that both should be referred to Portlock's species.

### *Euphemus*, sp.

Two poor specimens, with a finely reticulate ornament, were obtained at Torwood Glen, Stirlingshire. I don't think that they belong to any described species, but the shells are much too imperfect to serve as types for a new species. Nos. T1776[B], T1799[B].

### *Bellerophon Marcouianus*, Geinitz, 1866. (Pl. II. fig. 56.)

*Bellerophon Marcouianus*, Geinitz, 1866, *Carb. und Dyas in Nebraska*, p. 7, Tab. i. fig. 12.
„ „ Meek and Hayden, 1872, *Fin. Rep. U.S. Geol. Surv. Nebraska*, p. 226, pl. xi. fig. 13, *a*, *b*.

*Observations.*—A single species from Torwood Glen must, I think, be referred to the species figured by Conrad from the Lower Coal Measures of Western Virginia. Meek figures a fragment only, but this shows the characteristic keel. The Scotch specimen is very badly preserved: the strong median imbricated ridge is well seen, but the rest of the shell, though not crushed, is so encrusted by mineral matter that the surface of the valve is not to be made out. I know no figured shell except the North American species which has such a strongly marked and peculiarly ornamented median ridge.

TABLE SHOWING THE LAMELLIBRANCH FAUNA OF THE COAL MEASURES OF NEBRASKA, AND THE OCCURRENCE OF THE SAME SPECIES IN EUROPE.

| | Nebraska. | Scotland. | Congleton Edge. | Hazel Hill. | Base of Bristol Coal Measures. | Russia. |
|---|---|---|---|---|---|---|
| *Limatulina alternata*, M'Coy, sp., | | × | | | | |
| *Palæolima retifera*, Shumard, | × | | | | × | |
| *Entolium aviculatum*, Swallow, sp., | × | | | | | × ‡ |
| *Nucula Beyrichi*, V. Schaur. ? | × | | | | | |
| ,, *gibbosa*, Flem., | | × | | | | |
| ,, *ventricosa*, Hall, | × | | | | | |
| *Yoldia subscitula*, M. and H., | × | | | | | |
| *Nuculana lævistriata*, M. and W., sp., | × | × | | | | |
| ,, *attenuata*, Flem., sp., | | × | | | | |
| *Ctenodonta lævirostris*, Portlock, sp., | | × | | | | |
| *Grammatodon tenuistriata*, M. and W., sp., | × | × | | | × | × * |
| *Protoschizodus curtus*, M. and W., sp., | × | × | | | | |
| *Schizodus Wheeleri*, Swallow, sp., | × | × | | | | × †‡ |
| *Avicula longa*, Geinitz, | × | | | | | |
| ,, *? sulcata*, Geinitz, | × | | | | | |
| *Pseudomonotis radialis*, Phill., sp., | × | | | | | × ‡ |
| *Myalina Swallovi*, M'Chesney, | × | | | | | |
| ,, *subquadrata*, Shumard, | × | | | | | |
| ,, *perattenuata*, M. and W., | × | | | | | |
| ,, *Verneuillii*, M'Coy, | | × | | | | |
| *Aviculopecten occidentalis*, Shumard, sp., | × | | | | | |
| ,, *neglectus*, Geinitz, sp., | × | × | | | | |
| ,, *carboniferus*, Stevens, sp., | × | | × | × | | × ‡ |
| ,, *coxanus*, M. and W., | × | | | | | |
| ,, *obliquus*, sp. nov., | | × | | | | |
| ,, *regularis*, sp. nov., | | × | | | | |
| *Pterinopecten papyraceus*, Sow., sp., | | × | | | × | |
| ,, *Whitei*, Meek, sp., | × | × | | | | |
| *Posidoniella lævis*, Brown, sp., | | × | × | | × | |
| *Aviculopinna americana*, Meek, | × | | | | | |
| *Pinna peracuta*, Shumard, | × | | | | | |
| *Modiola ? subelliptica*, Meek, | × | | | | | |
| *Pleurophorus oblongus*, Meek, | × | | | | | × ‡ |
| *Sanguinolites occidentalis*, M. and H., sp., | × | × | | | | |
| *Edmondia reflexa*, Meek, | × | × | | | | |
| ,, *glabra*, Meek, | × | | | | | |
| ,, *nebrascensis*, Geinitz, sp., | × | × | | | | × †‡ |
| ,, *subtruncata*, Meek, | × | | | | | |
| ,, *aspinwallensis*, Meek, | × | | | | | |
| ,, *Lyellii*, Hind, | | × | | | | |
| ,, *sulcata*, Phill., sp., | | × | | | | |
| *Allorisma reflexa*, Meek, | × | × | | | | |
| ,, *Geinitzi*, Meek, | × | | | | | |
| ,, *subelegans*, Meek, | × | | | | | |
| ,, *granosa*, Shumard, sp., | × | | | | | |
| ,, *subcuneata*, M. and H., | × | | | | | × ‡ |
| *Tellinomorpha Hindii*, Bolton, | | × | | | × | |
| *Solenomorpha cylindrica*, sp. nov., | | × | | | | |
| *Solenomya brevis*, sp. nov., | | × | | | | |
| ,, *cylindrica*, sp. nov., | | × | | | | |
| *Prothyris elegans*, Meek, | × | × | | | | |
| *Solenopsis solenoides*, Geinitz., sp., | × | | | | | |

* Tschernyschew, "Obercarbonischen Brachiopoden d. Ural u. d. Timan," *Mém. Com. Géol. Russie*, 1902.

† Stuckenberg, "Die Fauna der obercarbon. Suite des Wolgadurbruches bei Samara," *Mém. Com. Géol. Russie*, 1905, Livr. 23.

‡ Jakowlew, "Die Fauna der oberen Abtheilung der Palaeozoischen Ablagerungen im Donetz Bassin: Die Lamellibranchiaten," *Mém. Com. Géol. Russie*, 1903.

## APPENDIX.

Since completing and presenting my account of the lamellibranch fauna in the Millstone Grit in Scotland, the following specimens have been collected by the officers of the Geological Survey from the cores of the Plean Bore near Stirling.

### *Edmondia nebrascencis*, Geinitz, sp., 1866. (Pl. II. fig. 34.)

*Astarte nebrascencis*, Geinitz, 1866, *Carb. und Dyas in Nebraska*, p. 16, Tab. i. fig. 25.
*Edmondia?* „ Meek, 1872, *Fin. Rep. U.S. Geol. Surv. Nebraska*, p. 214, pl. x. fig. 8, *a*, *b*.
„ „ Miller, 1889, *N. Amer. Geol. and Pal.*, p. 479.

*Specific Characters.*—Shell slightly transverse, subovate, only moderately gibbose, unequilateral. The anterior end is short, its margin regularly rounded. The inferior margin is broadly curved. The posterior border is bluntly rounded. The hinge line is slightly arcuate. The umbones are small, slightly elevated, placed at the junction of the anterior and middle thirds of the hinge line.

*Interior.*—Not yet examined.

*Exterior.*—The surface is ornamented by concentric, fine, raised, fairly equidistant linear ridges which separate moderately wide concentric sulci which are finely linear transversely. This marking is more characteristic in the new parts of the valve, towards the inferior margin; in the umbonal or juvenile part of the shell the lines and grooves are crowded. Under the microscope very fine radiating lines are seen.

*Dimensions.*—A right valve from Nebraska in my collection measures: antero-posteriorly, 22 mm.; dorso-ventrally, 17 mm.

*Locality.*—Stirlingshire, Sheet 24 N.W., Rosehill diamond bore, $1\frac{1}{2}$ mile E. of Plean.

*Observations.*—Some half-dozen specimens of this species have been obtained from the diamond bore at Rosehill. *E. nebrascensis* is very closely related to *E. M'Coyii*, Hind, but it has some slight differences in the ornament. The concentric lines are more sharply linear and finer, especially in the older part of the shell, and in one specimen I made out the radiating markings mentioned by Meek in his species. In general shape there is no real difference between the species, and they are very closely allied, but *E. M'Coyii* is the more gibbose of the two. I have a series of fine specimens from Nebraska, and have been able to compare these with the Scotch examples and the series of shells which served me for the study of my species *E. M'Coyii*. Unfortunately the Scotch examples are very badly preserved; but specimens $T^{4643B?}_{4644B}$, Pl. II. fig. 34, show the characteristic marking of the valve. The series from Rosehill show a greater tendency to variation of the ornament in the older and younger portions of the shell than my American series. *Sanguinolites occidentalis* occurs in the Shale with *E. nebrascensis*.

## EXPLANATION OF PLATES.

### Plate I.

Fig. 1. *Palæolima retifera*, Shumard, sp. × 3/2. Page 337.
Figs. 2, 3. *Aviculopecten regularis*, sp. nov. × 3/2. Page 341.
Figs. 4–6. *Aviculopecten neglectus*, Geinitz, sp. × 2. Page 341.
Fig. 7. „ „ „ 4. Page 341.
Fig. 8. *Aviculopecten obliquus*, sp. nov. × 2. Page 340.
Figs. 9, 10. *Limatulina alternata*, M'Coy, sp. Page 338.
Figs. 11, 12. *Aviculopecten Whitei*, Meek, right and left valves. Page 338.
Fig. 13. „ „ × 3/2. Page 338.
Fig. 14*. *Aviculopecten carboniferus*, Stevens, sp. × 3/2. Page 339.
Fig. 15. *Posidoniella lævis*, Brown, sp., a left valve. × 3. Page 342.
Fig. 16. *Myalina Verneuillii*, M'Coy, sp. Page 342.
Fig. 17. *Nuculana lævistriata*, Meek and Worthen, sp. × 3/2. Page 343.
Figs. 18, 19. *Nucula gibbosa*, Flem. × 4 Page 343.
Fig. 20. *Modiola subelliptica*, Meek. × 3. Page 343.
Fig. 21. *Grammatodon tenuistriata*, Meek and Worthen, sp. × 21. Page 344.
Figs. 22, 23. *Protoschizodus curtus*, Meek and Worthen, sp. × 3/2. Page 345.
Figs. 25–28. *Schizodus Wheeleri*, Swallow, sp. Page 345.
Figs. 29, 30. ? *Anthracomya truncata*, sp. nov. Page 346.

All specimens are from Scotland, and in the Museum of the Geological Survey of Scotland, with the exception of *. This specimen is from Pately Bridge, Yorkshire, and is in the Collection of the Geological Survey, Jermyn St.

### Plate II.

Figs. 31, 32. *Edmondia excentrica*, sp. nov. Page 347.
Figs. 33. „ *sulcata*, Phillips, sp. Page 348.
Fig. 34. „ *nebrascensis*, Geinitz, sp. Page 358.
Fig. 35. „ *Lyelli*, Hind. Page 348.
Figs. 36–38. *Sanguinolites occidentalis*, Meek and Hayden, sp. Page 348.
Fig. 39. ? *Allorisma reflexa*, Meek. Page 349.
Figs. 40–42. *Tellinomorpha Hindii*, Bolton. × 3/2. Page 349.
Figs. 43, 44. *Solenomorpha cylindrica*, sp. nov. × 3. Page 350.
Fig. 45–47. *Solenomya brevis*, sp. nov. Figs. 45 and 47 × 2. Page 351.
Figs. 48–50. *Prothyris elegans*, Meek. × 3/2. Page 353.
Fig. 51. *Loxonema nanum*, de Koninck. × 3. Page 353.
Figs. 52, 53. *Naticopsis brevispira*, de Ryckholt, sp. × 3. Page 354.
Fig. 54. *Entalis Meekianum*, Geinitz, sp. × 3/2. Page 355.
Fig. 55. *Ptychomphalus Marcouianus*, Geinitz, sp. × 2. Page 354.
Fig. 56. *Bellerophon Marcouianus*, Geinitz. × 3/2. Page 356.
Figs. 57, 58. *Euphemus d'Orbignyi*, Portlock, sp. × 3/2. Page 355.
Fig. 59. *Macrocheilina*, sp. Page 354.
Figs. 60, 61. *Solenomya cylindrica*, sp. nov. Page 351.

All the figured specimens are from Scotland, and are in the Museum of the Geological Survey of Scotland.

1 × 3/2.

2 × 3/2.

3 × 3/2.

4 × 2/1.

5 × 2/1.

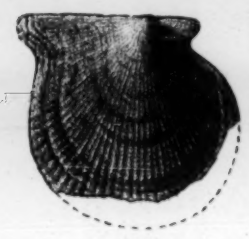
9.

8 × 2/1.

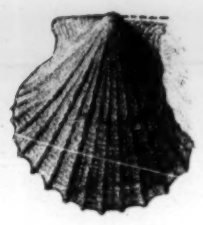
6 × 2/1.

7 × 4/1.

10.



11.



14 × 3/2.

13 × 3/2.

12.

16.

15 × 3/1.

17 × 3/2.

18 × 4/1.

19 × 4/1.

20 × 3/1.

21 × 2/1.

22 × 3/2.

23 × 3/2.

25.

26 × 2/1.

29 × 3/1.

24.

27.

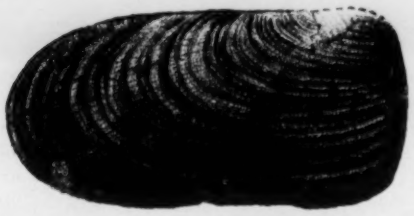
28.

30 × 3/1.

A.H. Searle, del et lith.

31 × 3/2.

32 × 3/2.



33.

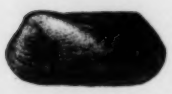
34.

60 × 3/2.

61 × 3/2.

35.

36.



37.

38.

40 × 3/2.

43 × 2/1.

44 × 2/1.

39 × 3/2.

41 × 3/2.

42 × 3/2.

48 × 3/2.

45 × 2/1.

46.

47 × 2/1.

49 × 3/2.

50 × 3/2.

51 × 5/1.

52 × 5/1.

53 × 5/1.

54 × 3/2.

55 × 2/1.

56 × 3/2.

57 × 3/2.

58 × 3/2.

59 × 3/1.

A. H. Searle del. et lith.

# XVI.—On a New Species of Dineuron and of Botryopteris from Pettycur, Fife.

By R. Kidston, LL.D., F.R.S., F.R.S.E. (With One Plate.)

(Read May 4, 1908. MS. received same date. Issued separately August 25, 1908.)

Among the interesting specimens which have been yielded by the material of Calciferous Sandstone age (Culm), from Pettycur, near Burntisland, are a petiole of *Dineuron* and a very small species of *Botryopteris*. The former genus does not appear to have been previously discovered in Britain, and the present species is, as far as I am aware, only represented by a single example. The *Botryopteris*, in the form of fragments of petioles, is not infrequent, but its stems are of much more rare occurrence.

## I. *Dineuron ellipticum*, Kidston, n. sp. (Plate, figs. 1–3.)

The specimen which forms the subject of the following description consists of a single transverse section of an almost circular petiole, whose greater width is about 2·25 mm. (fig. 1).

The petiole possesses an outer zone of stout cortex about 0·60 mm. wide (fig. 1, *o.C.*), which is succeeded inwards by a narrow band of delicate inner cortex (fig. 1, *in.C.*). This was separated by an endodermis (fig. 1, *end.*) from the thin-walled elements of the stele, which have almost entirely disappeared, and the mass of xylem now lies on one side of the space which they originally occupied (fig. 1).

The xylem of *Dineuron ellipticum* consists of an elliptic mass whose greater diameter is about 0·70 mm. It is composed of large tracheæ without any admixture of parenchyma; towards its two extremities the tracheæ suddenly become smaller where they meet the protoxylem elements (fig. 2, *prx.*).

At the right side of the xylem mass, a short distance within its margin, is a circular opening surrounded by the protoxylem elements. According to Renault, this circular opening was originally filled with parenchyma,* which also occurs in a similar position in the stele of *Zygopteris duplex*, Will., sp.† ‡

At the left side of the stele a semicircular sinus is observable. This results from the separation of a portion of the xylem to form the outgoing pinna trace. There is, unfortunately, no clear evidence as to the mode of departure of the pinna trace, for the structure so interpreted by Renault in his *Dineuron pteroides* § is more probably an unequal division of the petiole stele. One can only suggest, from the great similarity of the stele of *Dineuron* to that of *Zygopteris duplex*, that a band was cut off alternately from

* In *Dineuron pteroides*, Renault, *Bassin houil. et perm. d'Autun et d'Épinac, Flore foss.*, deux. part., p. 22, 1896.

† *Rachiopteris duplex*, Will., *Phil Trans.*, vol. clxiv., p. 687, Plates.

‡ Several slides of *Zygopteris duplex* in my collection show this: Nos. 1315, 1314, 1313, etc.

§ Renault, *l.c.*, p. 23, fig. 19.

each end of the xylem to supply the pinnæ traces, which, as in *Zygopteris duplex*, possibly divided into two in their course through the cortex.

The metaxylem is multiseriate as seen in transverse sections of the tracheæ, while the protoxylem is apparently scalariform.

The soft elements of the stele have all decayed, and are only represented by carbonaceous fragments around its periphery.

The remains of the endodermis are seen at fig. 1, *end.*, and outside of this lies the inner cortex, composed of four or five rows of delicate parenchyma. This is succeeded by the outer cortex, formed of thick-walled prosenchyma, the component elements of which vary somewhat in the size of their lumen, but there is no regular arrangement of the larger and smaller elements. The peripheral portion of the cortex consists of smaller elements, but it is much destroyed and seems to have been of a more delicate structure than the zone lying immediately within it.

If one compares the description of *Dineuron ellipticum* with RENAULT's description of his *Dineuron pteroides*, the wisdom of placing the Pettycur plant in the genus *Dineuron* may at first sight be questioned; but if the figure of *Dineuron pteroides* be carefully examined, it will be seen that the tissue which occupies the central portion of the stele has much more the appearance of xylem than of parenchyma, as supposed by RENAULT. This circumstance, supported by the structure of the Pettycur plant, which agrees so completely with *Dineuron* in other respects, has led me to adopt this view, and a similar opinion seems to have been accepted by Mons. PAUL BERTRAND in his proposed classification of the *Zygopterideæ*.*

## II. *Botryopteris antiqua*, Kidston, n. sp. (Plate, figs. 4–12.)

Three stems of *Botryopteris antiqua* are shown on Plate I. figs. 4, 6, 7. The one given at fig. 4 shows two attached petioles, and that at fig. 7 a single attached petiole, while the stem at fig. 6 illustrates the branching of the stele (*s.'*, *s.''*) and also shows a petiole just freed from the stem.

Characteristic of the family to which it belongs, *Botryopteris antiqua* has a very small stem stele, when considered in relation to the size of the petioles to which it gives rise. The stele of the specimen seen at fig. 4 is only 0·40 mm. in diameter, while those of figs. 6 and 7 have a diameter of 0·50 mm.

The stem is irregular in form, owing to the departure of the petioles and roots. The cortex is formed of thick-walled prosenchymatous cells of small diameter and without intercellular spaces, the larger elements being placed towards the outer surface of the stem, which bears numerous hairs formed of a single row of cells.

The circular stem stele is formed of very small tracheæ, without any admixture of parenchyma. Stem protoxylems are not distinguishable (fig. 5). In longitudinal

* "Classification des Zygoptéridées d'après les caractères de leurs traces foliaires," *Comptes rendus*, 4th November 1907.

section the tracheæ are seen to possess scalariform thickenings without the occurrence of any porose markings.

None of the stems yet met with show the departure of the leaf-trace from the stele, but in several of them the leaf-traces are seen in their passage through the cortex.

At fig. 4, two petioles are being given off, apparently in spiral series; at figs. 6 and 7, one is seen on each stem, though in the former case it has probably become free.

The petioles, which are larger than the stems from which they arise, are circular or slightly oval in form, the largest met with attaining a diameter of 2·20 mm., with a leaf-trace 0·75 mm. in its greatest width. The leaf-trace is thus a half larger than the diameter of the stele of the stem.

The cortex of the petioles forms a broad zone of thick-walled prosenchymatous cells, the smaller of which lie at the periphery, while the larger elements are towards the centre of the zone, whence they decrease in size towards the endodermis, though even here they are larger than those of the peripheral area (fig. 6, *pet.*).

The endodermis is clearly defined by its dark contents, and is seen at fig. 8, *end.*

The whole of the soft elements of the leaf-trace have almost entirely disappeared, and when any fragments remain they are too imperfectly preserved to admit of a detailed description. The leaf-trace thus comes to occupy the centre of a clear space, or has fallen to one side (fig. 4, *pet.'*, *pet.''*; fig. 6, *pet.*; fig. 9).

In form the leaf-trace is oval, with one side slightly flattened, its more pointed or adaxial side being formed of protoxylem elements (fig. 8, *prx.*). In their distribution, however, the protoxylem elements are very irregular, and though their usual condition is to form a prominent band-like group at the apex of the trace, they occasionally have a greater or less lateral extension in the form of a narrow band down both sides of the xylem, or even extend some distance on the abaxial surface (fig. 8, *prx.*). At other times they are almost entirely limited to the adaxial margin, with a few isolated elements scattered along its lateral margins; but in no case do the protoxylems form teeth as in the other known species of the genus.

In longitudinal section the protoxylem elements are seen to be scalariform.

The metaxylem of the leaf-trace is composed of large tracheæ arranged without any definite order, but which become slightly smaller as they abut on the protoxylem (fig. 8). Their walls are porose.

The petioles underwent bifurcation. At fig. 11 an early stage in the dichotomy of a petiole is seen. Here the trace has become transversely elongated, and an indentation has appeared on one side. At fig. 12 the same petiole trace is seen divided into two equal arms.

The pinnæ appear to have been alternate, and their traces arise as small protuberances on the trace of the petiole (fig. 9, *pin.*). A further stage in their departure is seen at fig. 10, *pin.*, where the pinna trace is free from that of the petiole, though still enclosed in a common cortex. The protoxylem of the pinna trace is adaxial to the trace of the petiole.

The roots which rise direct from the xylem of the stem (fig. 6, *r.*) are very small, and contain a typical diarch strand composed of scalariform tracheæ.

The foliage and fructification of *Botryopteris antiqua* are unknown.

*Botryopteris antiqua* is a typical member of the genus, though perhaps its smallest species, and is easily distinguished by its minute size and the protoxylem elements of the leaf-trace being evenly distributed and not forming prominent teeth as in the other known species. The tracheæ of the stem are scalariform, not porose.

The general character of growth of *Botryopteris antiqua* was that of a fern with a branching stem of slender dimensions which bore petioles of large size when compared with the stem from which they originated, and that must have supported itself by scrambling amongst the surrounding vegetation.

It is an interesting point to notice the progressive development of the protoxylem in the form of prominent teeth. In *Botryopteris antiqua*, from the Calciferous Sandstone series (Culm), protoxylem teeth are absent; in *Botryopteris hirsuta*, Will., sp., from the Lamarkian series,* they are very distinct, and in some specimens even prominent; while in *Botryopteris forensis*, Renault, from the Upper Coal Measures of Grand-Croix, they form long, narrow prolongations. There seems to be a tendency in the petiole trace to become more simple in form as traced back in geological time.

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## EXPLANATION OF PLATE.

[*s.* = stele; *prx.* = protoxylem; *in.C.* = inner cortex; *o.C.* = outer cortex; *end.* = endodermis; *pet.* = petiole; *r.* = root; *h.* = hairs; *pin.* = pinna.]

Figs. 1–3. *Dineuron ellipticum*, Kidston, n. sp.

Fig. 1. Trans. section of petiole. × 30. Slide No. 57.
Fig. 2. Trans. section of stele. × 70.
Fig. 3. Trans. section of protoxylem group. × 160.

Figs. 4–12. *Botryopteris antiqua*, Kidston, n. sp.

Fig. 4. Trans. section of stem giving off two petioles. × 30. Slide No. 1084.
Fig. 5. Trans. section of stele of last specimen. × 70.
Fig. 6. Trans. section of stem showing division of stele, petiole, roots, and hairs. × 15. Slide No. 549c.
Fig. 7. Trans. section of stem giving off a petiole × 15. Slide No. 782.
Fig. 8. Trans. section of leaf-trace. × 80. Slide No. 508.
Fig. 9. Trans. section of petiole giving off pinna. × 30. Slide No. 1347.
Fig. 10. Trans. section of petiole giving off pinna. × 30. Slide No. 1086.
Fig. 11. Trans. section of petiole showing early stage of dichotomy of leaf-trace. × 30. Slide No. 1348.
Fig. 12. Trans. section of petiole showing leaf-trace dichotomously divided. × 30. Slide No. 1346.

All the figured specimens are in the Author's collection.

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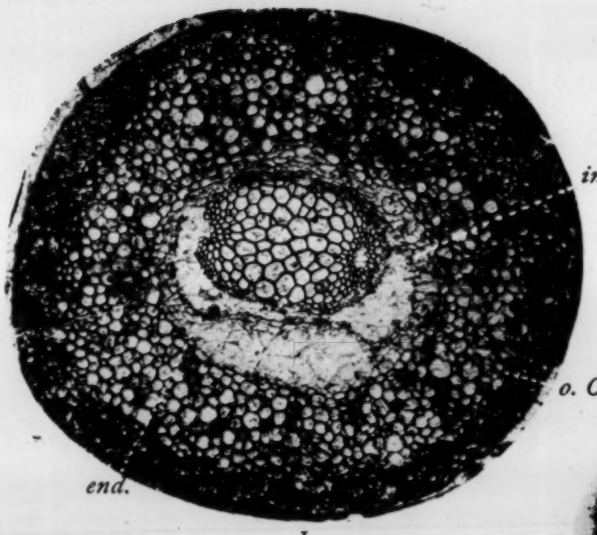
* KIDSTON, *Quart. Journ. Geol. Soc.*, vol. lxi., p. 320, 1905.

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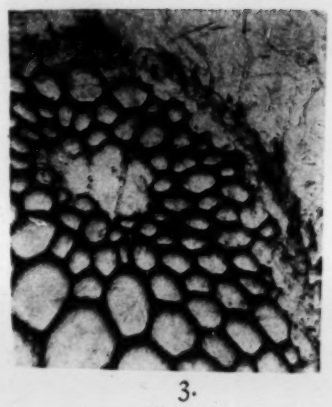

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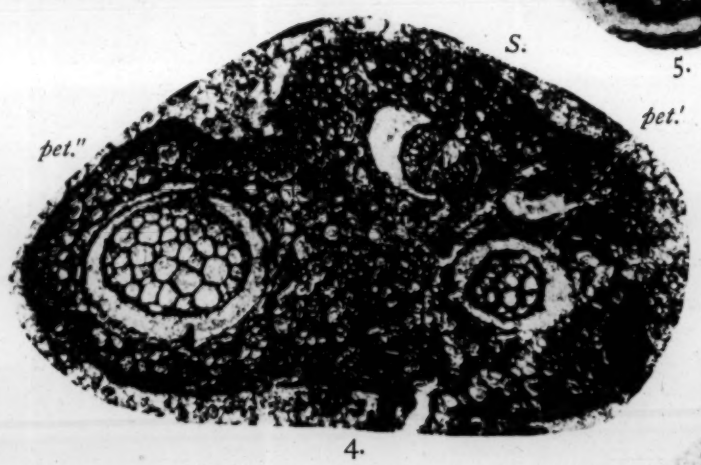


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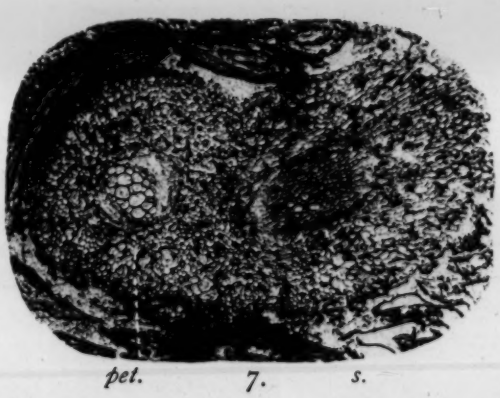


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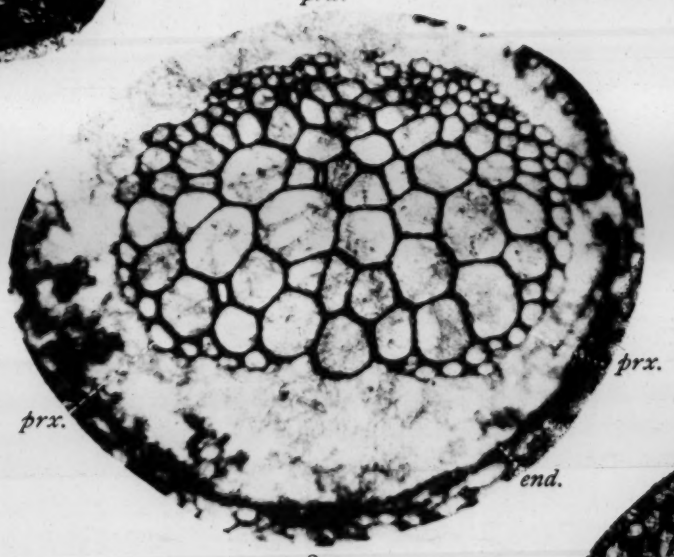


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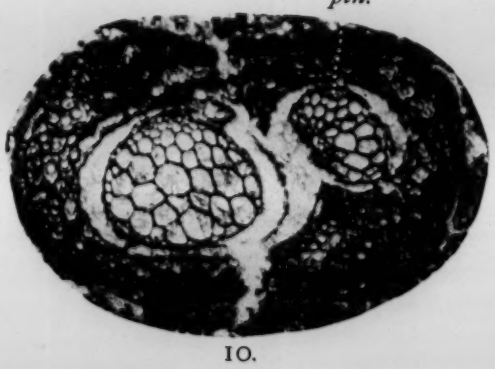


10.

11.

12.

Figs. 1–3.—DINEURON ELLIPTICUM. *Kidston, n. sp.*

Figs. 4–12.—BOTRYOPTERIS ANTIQUA. *Kidston, n. sp.*

# XVII.—The Craniology, Racial Affinities, and Descent of the Aborigines of Tasmania.

By Principal Sir Wm. Turner, K.C.B., D.C.L., F.R.S. (With Three Plates.)

(Read July 6, 1908. Issued separately October 16, 1908.)

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## Introduction.

The Anatomical Museum of the University of Edinburgh contains a valuable collection of the skulls of the aborigines of Tasmania, which has not as yet been described. As the skulls of this now extinct people are limited in number in museums, and as the opportunity of collecting additional specimens no longer exists, I have thought that an account of their characters, a detailed statement of their measurements on lines similar to those pursued in my previous craniological memoirs, and a comparison of their conformation with that of the Tasmanian skulls in other collections, as described by previous writers, would be of interest to anthropologists, and might assist in the preparation of a summary of their most constant features. Consideration of the affinities and possible descent of the Tasmanians may also be appropriately included in the Memoir.

The collection began to be formed about the end of the first quarter of the last century. The first specimen in course of time—an adult male—was acquired by Professor Alexander Monro *tertius* (xxx. 1). He referred to it as a skull from Van Diemen's Land in his *Elements of the Anatomy of the Human Body*,* in a chapter entitled, "On the distinctions in the skull of the male and female, and of the distinctions of the skulls of different nations."

During the tenure of office of his successor, Professor John Goodsir, additional Tasmanian skulls were acquired for the Anatomical Museum. One of these, an adult male, is marked Van Diemen's Land, but with no other history (xxx. 5). Another, an aged edentulous male (xxx. 4), was presented by C. Gray, Esq. The skull-cap had been previously sawn off for the removal of the brain. The outer table of the parietal bones, at and near the middle of the sagittal suture, showed a large eroded patch, and

* Second edition, p. 196, Edinburgh, 1831. Monro *tertius* died in 1859. I became acquainted with him in 1854, about which time he was having photographs made of the most interesting skulls in his collection. I possess a photograph of the skull, No. 52, referred to in the text, marked Van Diemen's Land in Monro's handwriting. Three measurements of the skull are given in Table ii., p. 204, of his *Elements of Anatomy*, but they are incorrectly stated.

on other parts of the parietal and frontal bones numerous shallow indentations were present which somewhat modified the contour and the general appearance of the cranium. They were possibly due to pathological conditions, or may have been produced by blows of the Tasmanian weapon named the waddy.* An adult male skull (xxx. 6) was presented as from Tasmania, to the late Professor Goodsir, shortly before his death in 1867. The bones were discoloured, as if the skull had been buried, and the outer table at the vertex and on the right parietal was abraded and the diplöe was partially exposed.

During my incumbency of the Chair of Anatomy, other specimens were obtained. In 1870 an imperfect skull (xxx. 8), consisting of the frontal, both parietals, the supra-inial part of the occipital, the left temporal, and the right malar, was given by Mr J. Grant; it was marked "extinct race V.D.L.," and from its appearance had probably been buried. Another imperfect specimen, marked "skull of an aborigine found at Bridgewater, presented by Mr Brent" (xxx. 9), consisted of the frontal and right parietal bones, obviously those of a young person. In October 1888 one of my pupils, Dr Lloyd H. Oldmeadow, presented to me the skull of an adult aboriginal male (xxx. 2) which he had brought from Hobart. It had been given to him by Dr E. M. Crowther of that town, and had been in the collection which had belonged to his father, Mr W. L. Crowther; it was believed to be the skull of one of the last of the aborigines, and indeed possibly that of William Lanné, the last male to survive. In February 1889 an adult skull marked Tasmanian was given to me by Mr J. C. Robertson. It had previously been in the possession of Mr Seal, a member of one of the earliest families to settle in Tasmania, and was regarded by him as that of an aborigine; it has female characters, and is marked xxx. 3 in Table I.†

The collection in the Phrenological Museum of the Henderson Trustees, now lodged in the Anatomical Museum of the University, contains an adult male skull which is marked Van Diemen's Land. It is numbered 231 in the manuscript catalogue of that collection, compiled in 1858, though it had undoubtedly been in the collection some years before that date. Its number in the catalogue of the Anatomical Museum is xxx. 7.

About the time when Monro *tertius* obtained the skull from Van Diemen's Land already referred to, Professor Robert Jameson had in his Museum of Natural History the skull of an aborigine marked Van Diemen's Land, which was also examined by Monro, who gave some measurements in Table ii., p. 204, in his chapter on the distinctive features of the skulls of different nations. The contents of Jameson's great museum were transferred to a department of the State in 1854, and they are now lodged in the Royal Scottish Museum, Edinburgh. The characters of the skull are embodied in the following description.

* The waddy, about 2 feet long, was made of hard, heavy wood, sometimes knobbed at one end, which could be used as a club, or could be thrown with a rotary motion either in battle or in the pursuit of prey. Barnard Davis, in his *Thesaurus Craniorum* and Supplement, refers to four Tasmanian skulls in his collection which showed marks of injury on the vault, the character of which is not specified, but may have been due to blows from the waddy.

† The Tasmanian crania are Group xxx. in the Catalogue of the collection of Crania in the Anatomical Museum of the University. The specimens in each group have consecutive numbers.

## Table I.

### *Tasmanian Crania in Edinburgh Museums.*

### Group XXX.

| | Monro | 2 | 3 | 4 | 5 | 6 | H.T. 231 | 8 | 9 | Jame-son. |
|---|---|---|---|---|---|---|---|---|---|---|
| Collection number, | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Age, | Ad | Ad. | Ad. | Aged. | Ad. | Ad. | Ad. | Ad. | Juv. | Ad. |
| Sex, | M. | M. | F. | M. | M. | M. | M. | M. | | M. |
| Cubic capacity, | 1215 | 1245 | 1260 | 1245 | 1140 | 1270 | 1430 | ... | ... | 1100 |
| Glabello-occipital length, | 183 | 186 | 78 | 181 | 181 | 181 | 190 | 191 | ... | 175 |
| Basi-bregmatic height, | 132 | 129 | 130 | 132 | 133 | 134 | 135 | ... | ... | 125 |
| *Vertical Index*, | *72·1* | *69·4* | *73·* | *72·9* | *73·5* | *74·* | *71 1* | ... | ... | *71·4* |
| Minimum frontal diameter, | 97 | 91 | 91 | 95 | 92 | 95 | 93 | 98 | 91 | 90 |
| Stephanic diameter, | 99 | 100 | 103 | 111 | 103 | 110 | 101 | 102 | 110 | 100 |
| Asterionic diameter, | 99 | 117 | 105 | 102 | 106 | 100 | 115 | ... | ... | 102 |
| Greatest parieto-squamous breadth, | 130s. | 139p. | 132s. | 128s. | 134s | 125p. | 141p. | 141s. | ... | 127s. |
| *Cephalic Index*, | *71·* | *74·7* | *74·2* | *70·7* | *74·* | *69·1* | *74·2* | *73·8* | ... | *72·6* |
| Horizontal circumference, | 510 | 511 | 499 | 494 | 505 | 495 | 524 | ... | ... | 489 |
| Frontal longitudinal arc, | 126 | 120 | 120 | 122 | 132 | 126 | 130 | 128 | 132 | 120 |
| Parietal, „ „ | 127 | 133 | 126 | 126 | 122 | 130 | 134 | 115 | 135 | 119 |
| Occipital, „ „ | 105 | 103 | 110 | 102 | 113 | 113 | 118 | ... | ... | 103 |
| Total, „ „ | 358 | 356 | 356 | 360 | 357 | 359 | 382 | ... | ... | 342 |
| Vertical transverse arc, | 291 | 288 | 278 | 284 | 290 | 285 | 301 | ... | ... | 272 |
| Basi-transverse diameter, | 122 | 121 | 113 | 119 | 117 | 111 | 127 | ... | ... | 117 |
| Vertical transverse circumference, | 413 | 409 | 391 | 403 | 407 | 396 | 428 | ... | ... | 389 |
| Length of foramen magnum, | 36 | 37 | 34 | 32 | 34 | 33 | 35 | ... | ... | 35 |
| Basi-nasal length, | 107 | 101 | 98 | 107 | 96 | 107 | 100 | ... | ... | 96 |
| Basi-alveolar length, | 105 | 98 | 102 | ... | 94 | 108 | 101 | ... | ... | 101 |
| *Gnathic Index*, | *98·1* | *97·* | *104·1* | ... | *97·9* | *100·9* | *101·* | ... | ... | *105·2* |
| Total longitudinal circumference, | 501 | 494 | 488 | 494 | 487 | 499 | 517 | ... | ... | 473 |
| Interzygomatic breadth, | 138 | 130 | ... | 137 | ... | 128ap. | 138 | ... | ... | 120 |
| Intermalar „ | 121 | 117 | 113 | 122 | 111 | 114 | 119 | ... | ... | 115 |
| Nasio-mental length, | ... | ... | 96 | ... | ... | ... | ... | ... | ... | ... |
| *Nasio-mental complete facial Index*, | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Nasio-alveolar length, | 71 | 61 | 56 | .. | 61 | 68 | 56 | ... | ... | 64 |
| *Maxillo-facial Index*, | *51·4* | *46·9* | ... | ... | ... | *53·1* | *40·5* | ... | ... | *53·3* |
| Nasal height, | 54 | 49 | 41 | 43 | 47 | 50 | 44 | ... | ... | 46 |
| Nasal width, | 30 | 28 | 25 | 28 | 28 | 26 | 29 | ... | ... | 29 |
| *Nasal Index*, | *55·6* | *57·1* | *61·* | *65·1* | *59·6* | *52·* | *65·9* | ... | ... | *63·* |
| Orbital width, | 44 | 39 | 39 | 41 | 38 | 39 | 37 | ... | ... | 41 |
| Orbital height, | 30 | 31 | 33 | 32 | 32 | 32 | 29 | ... | ... | 29 |
| *Orbital Index*, | *68·2* | *79·5* | *84·6* | *78·* | *84·2* | *82·* | *78·4* | ... | ... | *70·7* |
| Palato-maxillary length, | 59 | 54 | 58 | ... | 55 | 60 | 57 | ... | ... | ... |
| Palato-maxillary breadth, | 69 | ... | 68 | ... | 61 | 65 | 65 | ... | ... | ... |
| *Palato-maxillary Index*, | *116·9* | ... | *117·2* | ... | *110 9* | *108·3* | *114·* | ... | ... | ... |
| *Nasio-malar Index*, | *109·* | *108·* | *104·* | *103·8* | *108* | *108·* | *106·* | ... | ... | *106·9* |
| *Cranio-facial Index*, | *75·4* | *69·8* | ... | *75·6* | ... | *71·1* | *72·6* | ... | ... | *68·5* |
| Lower jaw. Symphysial height, | ... | ... | 29 | Edentulous jaw. | ... | ... | ... | ... | ... | ... |
| Lower jaw. Coronoid „ | . | ... | 56 | | ... | ... | ... | ... | ... | ... |
| Lower jaw. Condoloid „ | ... | ... | 56 | | ... | ... | ... | ... | ... | ... |
| Lower jaw. Gonio-symphysial length, | ... | ... | 87 | | .. | ... | ... | ... | ... | ... |
| Lower jaw. Inter-gonial width, | ... | ... | 91 | | ... | ... | ... | ... | ... | ... |
| Lower jaw. Breadth of ascending ramus, | ... | ... | 33 | | ... | ... | ... | ... | .. | ... |

## Description of Tasmanian Skulls. (Plates I.–III.)

Measurements of the skulls are given in Table I., in which they are discriminated by the catalogue numbers, Group xxx. No. 1, *e.s.* With two exceptions they were adult males, though two were advanced in years. xxx. 3 was probably that of a woman, and the fragmentary calvaria xxx. 9 was that of a youth. The lower jaw was present in only two specimens, in one of which, the aged xxx. 4, it was edentulous. No definite statement can be made of the parts of the island in which the majority of the skulls were procured, but two (xxx. 2, 9) were obtained in or near Hobart Town.

*Norma verticalis.*—The skulls were elongated, and dolichocephalic in the proportions of length and breadth. In three specimens the outline of the cranium was ovoid, but in the others the parietal eminences were so prominent, more especially in xxx. 2, 7, that they broke the uniformity of the sides of the cranium, the outline of which approximated to the pentagonal form. Behind the eminences the width of the cranium rapidly diminished into the occipital region.

The frontal eminences were distinct. The frontal bone in the males showed in front of the bregma an area almost triangular in form, the broad base of which was at the coronal suture, whilst the apex approached a point between the frontal eminences; its surface was convex from side to side and from base to apex. It was bounded laterally by a shallow, concave depression which extended backwards across the suture on to the parietal bone, as far as or somewhat beyond the parietal eminence. This depression was only feebly indicated in the single female skull in the collection. The temporal curved line was well marked in the male crania, and its anterior end formed the outer and lower boundary of the depression on the frontal bone. In two specimens the temporal line arched in the parietal region immediately above the eminences, and partially divided the depression on the vault into an upper and a lower area, the upper of which was the larger; but in the other skulls it intersected the eminence at or near the greatest projection and formed the lower boundary of the depression. The width of the cranium in the frontal region, as compared with the parietal or parieto-squamous diameter, was relatively small. The mean stephanic diameter was 103·2 mm.; the mean parieto-squamous diameter was 133 mm.; as the zygomatic arches were visible in the norma verticalis, the skulls were phænozygous.

The crania along the line of the sagittal suture were keeled, especially in its anterior half, though in some specimens in almost its whole length. In three skulls from 3 to 4 mm. behind the bregma the sagittal suture was depressed in a groove which was bounded on each side by a ridge which formed the upper boundary of the parietal depression; the groove widened as it passed backwards to the lambdoid suture. In the other skulls the groove, with its lateral bounding ridges, was either absent, or so faintly marked as to be scarcely perceptible, and the upper boundary of the parietal depression was formed by the sagittal keel itself. The keel, conjoined with the steep, lateral slope of the parietal bones down to the eminences, gave a definite, roof-shaped character to the

skulls, which, together with the shallow antero-posterior depressions in the fronto-parietal regions and the prominent parietal eminences, formed some of the distinctive features in the Tasmanian crania.

In order to give a pictorial illustration of these characters, I placed three of the skulls so as to obtain photographs of the frontal and the anterior part of the parietal regions as seen from above, and I have had "process" reproductions prepared. (Plate I., figs. 2–4.)*

The median frontal convexity, the shallow depression which bounded it on each side, extending backwards into the parietal region, the projecting parietal eminences, the relative narrowness of the frontal region with the phænozygous condition of the zygomata, are reproduced in the plate. I have also obtained tracings with Lissauer's apparatus of the vertical transverse arc of the cranial vault, to show the undulating outline in the

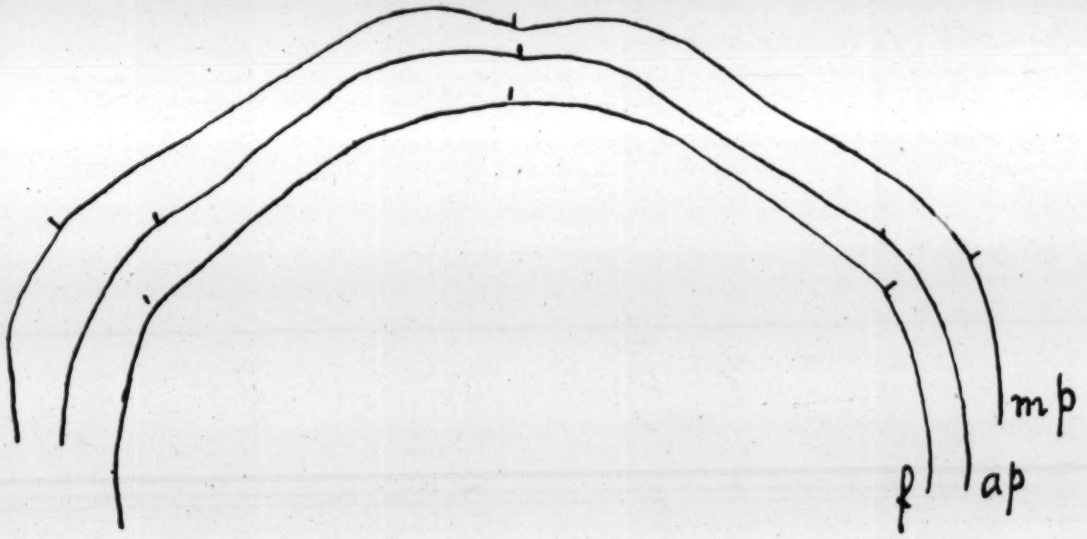


Fig. 1.

frontal region, in the antero-parietal region, and in the plane of the two parietal eminences.† (Fig 1, text.)

Below the parietal eminences the side walls of the cranium were only slightly bulging, though, as a rule, the greatest breadth was at or near the squamous suture. The parietal foramina were usually obliterated, and when present were very small. Between the obelion and the lambdoid suture the vault sloped gently downwards and backwards, and this part of the post-parietal region had a surface obliquely flattened from side to side, in no way to be mistaken for the vertical parieto-occipital flattening produced by pressure applied artificially during infancy. The general form of the skull corresponded with the *pentagonoides planum* of Sergi.

* These skulls are lettered in Table I., xxx., Nos. 2, 5, and 10.

† The frontal transverse arc *f* was taken 35 mm. in front of the bregma, the antero-parietal arc (*ap.*) was one cm. behind the bregma, whilst the mid-parietal arc (*m.p.*) was about the middle of the eminences. The tracings were of the skull from the collection of the late Professor Robert Jameson (Table I. No. 10). Professor Cunningham kindly traced them of the size of Nature with a Lissauer's apparatus in his possession. The short vertical lines on the vertex are in the position of the sagittal suture; those at the sides mark the temporal curved lines.

The suprainial part of the occipital squama formed a large rounded protuberance in the female skull (xxx. 3), a character which may perhaps be regarded as sexual rather than racial, and the vertical diameter following the curve from lambda to inion was 70 mm. In the male (No. 2) the protuberance was moderate, and its curve was 64 mm. In Nos. 4, 7, and the Jameson skull it was feeble; the length of the curve in No. 4, owing to the skull-cap being loose, could not be exactly stated, but in No. 7 it was 70 mm. and in the Jameson specimen 52 mm. In the Monro specimen No. 1 and in No. 5 the suprainial region was almost a plane surface; in No. 5 the inion practically formed the posterior pole of the cranium; in No. 1 the lambda-inial diameter was 60 mm.; in No. 5 only 43 mm. The feeble occipital protuberance in three males, and the flattened occipital squama in two others, proved that the occipital lobes of the cerebrum in these skulls could not have projected much beyond the posterior border of the cerebellum. The transverse curve of the occipital bone, immediately above the inion and between the asterionic angles, was 123 mm. in the Monro specimen No. 1, 126 in 3, 128 in 4, 133 in 6, 139 in the Jameson specimen, and 150, 153, and 155 mm. in Nos. 5, 2, and 7 respectively.

*Norma lateralis.*—The forehead receded somewhat in the male skulls, especially in No. 1, but it approached more to the vertical in the female No. 3. The glabella and supraciliary ridges were strong in the males, especially in the Monro specimen; in No. 6 each ridge was directly continued into the thick upper orbital border as a *torus supraorbitalis*, but in the others it was separated from it by the supraorbital notch or foramen. The frontal, between the outer end of the ridge and the temporal curved line, formed a *supraorbital trigone* and sloped obliquely backwards to the external orbital process. The frontal was not grooved for the passage of the supraorbital vessels or nerve above their foramen of exit. The nasion was deeply depressed. The nasal bones were entire in four skulls, and in them the bridge measured mesially, in a straight line, 13, 15, 17, and 17 mm. respectively; the bones were short and narrow, whilst deeply seated below the prominent glabella the bridge, though concave in profile and continuous with the very depressed nasion, had a shallow keel mesially. In each cranium the occipital longitudinal arc was the shortest, in seven the parietal was the longest, though as between the frontal and parietal the difference in six skulls was only from 1 to 4 mm. The crania rested behind on the mastoids in three specimens, but in the others either on the cerebellar fossæ or the occipital condyls. (Plates II., III.; figs. 6, 8, 10, 12.)

*Norma facialis.*—The floor of the nose was not separated from the incisive region by a sharp ridge, and the nasal floor was often continued smoothly into the incisive area. The maxillo-nasal spine was feeble, and usually continued into the nasal septum. The nasal height in the seven males ranged from 44 to 54 mm. and the mean was only 47·6. The width of the anterior nares in each specimen was more than half the height of the nose, and in some cases much wider. No nasal index was narrow or leptorhine, only one was mesorhine, the rest were platyrhine, and in four the index was above 60, the highest being 65·9; the mean of the series was 59·9. In the female skull the lower jaw was

complete and the nasio-mental length was 96 mm., but as the zygomatic arches were broken, the complete facial index could not be computed. In five skulls the maxillo-facial index ranged from 40·5 to 53·3; three were leptoprosopic, narrow faced, and in them the maxillary region was relatively narrow, as if pinched in laterally; one skull was chamæprosopic (40·5), low-faced, but the mean of the series (49) was mesoprosopic. In four skulls, not including the edentulous, the upper jaw, on inspection, showed none or but little alveolar prognathism, but in three the prognathism was distinct. The gnathic index obtained by Flower's method ranged from 97 to 105·2; two were in the orthognathic group, three were mesognathic, two were prognathic; the mean of seven skulls was 100·6, *i.e.* mesognathous. The canine fossæ were distinct, and in two they had unusual depth. The incisive fossæ were shallow in the orthognathic skulls, but were more marked in the prognathic. (Plates II., III.; figs. 7, 11.)

The nasio-malar index* ranged from 103·8 to 109; two skulls were platyopic, six mesopic, none pro-opic *i.e.* with a projecting profile; the presence of a slight keel in the bridge of the nose contributed to place the mean 106·7 in the mesopic group. The orbital aperture was transversely elongated and relatively low, the vertical diameter of the os planum was also low, and its anterior border had only a short articulation with the lachrymal. The supraciliary ridge and the upper border of the orbit projected in front of the plane of the lower border of the orbit. The outer border of the orbit was considerably behind the inner border, and the plane of the orbital aperture was oblique. The infraorbital suture was usually obliterated. The orbital index ranged from 68·2 to 84·6; no specimen was megaseme, two were mesoseme, six were microseme, and the mean index 78·2 was microseme. The interorbital width in six skulls ranged from 20 to 25 mm.; in two it was 27, in one 28 mm. The malar bones were small.

The hard palate in some skulls was shallow, in others it was moderate in height, but no specimen had a high vault. The palato-maxillary index ranged from 108·3 to 116·9, and the mean of five specimens was 113·4; one was dolichuranic, with a relatively long palate; two, brachyuranic, were more evenly proportioned in length and breadth; two, mesuranic,† had intermediate proportions. The lower jaw in the male (xxx. 4) was edentulous, and the senile characters were pronounced. In the female the mandible, though of moderate size, was well formed and with the muscular markings feeble; the chin was also feeble. The teeth were mostly lost from the maxillæ; when present they were, as a rule, worn by use, but were not stained; the alveoli were unabsorbed and the adult dentition had been completed. In the left upper dentary arcade of xxx. 2 the socket of a fourth molar was present, but the tooth had dropped out. The sockets for the incisors were not absorbed, and obviously the extraction of upper incisors at puberty had not been practised by these Tasmanians. One or more molars and pre-

* The nasio-malar index is computed by dividing the nasio-malar line × 100 by the bi-malar line; the index of a pro-opic or projecting profile is above 110, a platyopic or flat profile is below 106, while a mesopic profile has the index between 106 and 110.

† See "On the Craniology of the People of Scotland," *Trans. Roy. Soc.*, vol. xl. p. 6071, 1903, for explanation of these terms.

molars were preserved in each of seven skulls. In one the crown of the 1st molar was 12 mm. in antero-posterior and 12 mm. in lateral diameter, and the tooth may be regarded as megadont; in two others 10 by 11 mm. The crown of the 2nd molar was in one skull 10 by 12 mm., in another 10 by 11 mm. The wisdoms were usually lost, but the crown of one was 10 by 12 mm. in diameter. The crowns of the 1st and 2nd premolars in one skull were 6 by 9 mm. The teeth had been regularly arranged in their respective arcades, and the empty sockets were commodious.

The cranial sutures were usually simple, and the sagittal was the most strongly denticulated. In Nos. 1, 3 and 4, they were in course of senile obliteration; no skull was metopic.* No. 5 had a large epipteric bone on each side, and No. 2 had a small one in the right pterion. The Jameson skull had no sutural bones, but a strong process passed from the left squamous to the frontal and intervened between the parietal and alisphenoid. Five skulls had small Wormians in the lambdoid, and No. 1 had minute sutural bones in the left coronal.

The mastoids and inion were not massive, but the superior curved occipital line was sometimes strong and divided into an upper and a lower part separated by an intermediate area; No. 7 had two pea-like exostoses on the left parietal. No skull had a third condyl. In No. 1 the right external pterygoid was fused with the spine of the sphenoid and was pierced by two pterygo-spinous foramina; on the left side one foramen had its boundary incomplete. In No. 2 a similar fusion was present on the left side, pierced by two foramina. In some skulls the jugal processes were tuberculated.

The crania ranged, in maximum length, from 175 to 191 mm., and the mean length of nine was 182·8 mm. The parieto-squamous breadth ranged from 127 to 141 mm., and the mean was 138 mm.; the cephalic index ranged from 69·1 to 74·7, and the mean was 72·7; all the skulls were dolichocephalic. The basi-bregmatic height ranged from 125 to 135 mm., and the mean of eight skulls was 131·1; the vertical index ranged from 69·4 to 74, and the mean was 72·1, metriocephalic. In three skulls the height somewhat exceeded the breadth, but in five the breadth was greater than the height; the mean of the group was 138 mm. in breadth to 131 mm. in height. The cranio-facial index † was computed in six skulls, and ranged from 68·5 to 75·6; the mean of the series was 72·1, which differed only fractionally from the mean of the dolichocephalic index.

The cubic capacity was determined in eight skulls by the use of shot, in accordance with the method ‡ which I have employed for about twenty-five years in the study of the capacity of about six hundred crania of various races. The female skull measured 1260 c.c.; the seven males ranged from 1100 to 1430 c.c., and the mean capacity in this sex was 1235 c.c. The Jameson skull, which had the least internal capacity (1100 c.c.),

* Flower has shown that the skull of an old Tasmanian woman in the Museum of the Royal College of Surgeons is metopic, also the male skull in the Natural History Museum, South Kensington.

† The cranio-facial index is computed by the formula $\frac{\text{interzygomatic breadth} \times 100}{\text{maximum length}}$, the length = 100. See my Memoir on the natives of Borneo, etc., *Trans. Roy. Soc. Edin.*, part iii., p. 800, vol. xlv., 1907.

‡ Described in "*Challenger*" *Reports*, "Zoology," part xxix., 1884.

was the smallest in the external dimensions of length, height, and circumference; whilst No. 7, which had the greatest internal capacity (1430 c.c.), had large external dimensions in length, height, breadth, and circumference.

### Comparison with Tasmanian Skulls in other Collections.

As collections of Tasmanian skulls in several museums have been described by eminent anthropologists, I purpose to compare my specimens with those previously recorded. By way of preface, I shall state where these skulls are to be found.

Owen, in his descriptive catalogue of the osteological series in the Museum of the Royal College of Surgeons of England,* gave brief notes of nine Tasmanian crania at that time in the museum. In Flower's catalogue of the same museum measurements, in some cases short descriptions, are given of the specimens, which are now twenty in number,† two of which are associated with skeletons. Of these seventeen are adults, nine males, seven females, but the sex of one is not stated; whilst two others are youths and one is an infant. This museum also now contains the splendid collection formed by Barnard Davis, catalogued independently:‡ fifteen are Tasmanians, nine males, to one of which a skeleton belongs, and six are females. The characters of the skulls, both in the Davis and the Surgeons' collection, have also been generally described by J. G. Garson in a chapter in Ling Roth's treatise on the aborigines of Tasmania. The British Museum of Natural History at South Kensington possesses an adult male skeleton which formerly belonged to the Anthropological Institute. In the collection of crania in the Museum of the Army Medical Department, formerly at Fort Pitt, Chatham, afterwards at Netley, but now at Millbank, four skulls were catalogued by Dr G. Williamson as natives of Van Diemen's Land. Of these, only two, an adult male and a youth, can be regarded as Tasmanian.§

In 1872 M. Topinard published a critical study of the Tasmanian skulls in the museums in Paris, which contain nine specimens, five adult males, three females, and a youth of eleven years, and MM. De Quatrefages and Hamy have made the same crania the basis of an elaborate chapter in their great work *Crania Ethnica*. In 1862 Barkow figured the vertex and occipital surface of an adult Tasmanian skull in the museum at Breslau,‖ and additional details of its form, dimensions, and character have been subsequently given by Wieger in his catalogue ¶ of the Anthropological Collection in that museum.

* London, 1853.

† 1st edition, p. 198, 1879; 2nd edition, edited by C. Stewart, p. 337, 1907.

‡ *Thesaurus Craniorum*, p. 267, 1867, and Supplement, p. 63, 1875.

§ *Dublin Quarterly Journal of Medical Science*, vol. xxiv., 1857. The skulls are numbered in Williamson's catalogue Nos. 445, 446, 58, 59. On visiting the museum at Millbank a short time ago, Colonel Wardrop, the Commandant, kindly gave me permission to see the collection. Nos. 445, 446, have strong Tasmanian characters, and in 446 the wisdoms had not erupted and the basi-cranial synchondrosis was not ossified. No. 58 has apparently been lost. No. 59 is evidently, as Dr Williamson stated, not distinctively Tasmanian.

‖ *Comparative Morphologie*, Breslau, 1862, Plates x., xi.

¶ *Katalog*, Museum, Breslau, 1884.

In the Collection of crania in the Oxford University Museum are six adult skulls which have been regarded as Tasmanian. Measurements by Dr GABRIEL FARMER of this series were included in LING ROTH'S comprehensive treatise, and he abstracted the following notes from the museum catalogue:—Nos. 1 and 2 were received in 1864; No. 3 was given by the Rev. W. W. SPICER; Nos. 5 and 6 were obtained in 1887; whilst No. 4, said to have been brought by Captain Cook and to be Polynesian, was stated in Dr RIDD'S catalogue to be Tasmanian. As the skulls, according to FARMER'S table of measurements, ranged in the cephalic index from 70·5 (No. 1) to 82 (No. 4), I asked my friend Professor ARTHUR THOMSON to ascertain if any further information regarding their possible origin could be obtained, for the range given to the cephalic index gave one the impression that skulls other than Tasmanians might have been included in the series; but his reply was that nothing could be added to the notes abstracted by FARMER from the catalogue. Professor THOMSON very courteously undertook to have the skulls remeasured by two of his pupils, Mr F. H. S. KNOWLES and Miss BARBARA W. FREIRE-MARRECO, who have checked each other's measurements and rechecked them with the figures given in FARMER'S table. As their results differ in many respects from those given by FARMER, I have the consent of Professor THOMSON to reproduce them in Table II. of this memoir.

In the Museum at Hobart Town, Tasmania, are nineteen crania, which at one time were believed to be those of aborigines. They have now been carefully studied by Messrs HARPER and CLARKE,* with the result that only twelve specimens, six males and six females, one of which was much broken, were retained as genuine Tasmanians. Of the remainder, three were probably half-castes, and three were incorrectly classed. W. H. L. DUCKWORTH has described an adult male skull, the facial part of another male, a calvaria, and two lower jaws in the Anatomical Museum of the University of Cambridge;† the calvaria and one of the mandibles were presented by Mr JAMES BONWICK, the well-known writer on Tasmania. In the catalogue of the crania in the Museum in Philadelphia, J. AITKEN MEIGS marked with a query, No. 1343, as "Tasmanian of Van Diemen's Land," but without description or measurements. H. KLAATSCH has given, with figures, a series of comparative measurements of eight of the Tasmanian skulls in the museums in London and Paris.‡ He also stated that Professor v. LUSCHAN, in his private collection in Berlin, has five Tasmanian skulls purchased from the widow of Mr G. A. ROBINSON, who acted as Protector of the aborigines. I am not acquainted with any description of these specimens, nor have I any information of a Tasmanian skull said by BARNARD DAVIS to be in a museum in Vienna.

The crania catalogued in museums as Tasmanian, including those recorded in this memoir, which have been studied and described by anthropologists, and the measurements of which have been more or less fully recorded, are seventy-nine in number.

* *Papers and Proc. Roy. Soc. Tasmania*, for 1897, p. 97, 1898.
† *Journ. Anth. Inst.*, vol. xxxii., 1902; and *Cambridge Studies.*
‡ *Zeitsch. für Ethnologie*, Heft 6, 1903.

Of these, seventy-three are adults and six are young. Forty-two adults are regarded as males, twenty-six as females, whilst the sex of five is either doubtful or not specified.

TABLE II.

*Tasmanian Crania, Oxford University Museum.*

| | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 | No 6 |
|---|---|---|---|---|---|---|
| Collection number | 1017 | 1019 | 1020 | 1021 | 1021A | 1021B |
| Age, | Adol. | Ad. | Aged. | Ad. | Ad. | Ad. |
| Sex, | F. | F. | F.? | M.? | M. | F. |
| Cubic capacity, | 1200 | 1160 | 1120 | 1220 | 1180 | 1060 |
| Glabello-occipital length, | 185·5 | 174· | 181· | 181· | 174·5 | 166 |
| Basi-bregmatic height, | 125 | 133 | 122 | 128 | 128 | 126 |
| *Vertical Index*, | *67·4* | *76·4* | *67·4* | *70·7* | *73·3* | *75·9* |
| Minimum frontal diameter, | 90 | 96 | 91 | 95 | 98 | 87 |
| Stephanic diameter, | 100 | 111 | 104 | 110 | 113 | 106 |
| Asterionic diameter, | 104 | 105 | 98 | 104 | 99 | 100 |
| Greatest parieto-squamous breadth, | 132 | 127 | 129 | 142 | 135 | 131 |
| *Cephalic Index*, | *71·1* | *73* | *71·2* | *78·4* | *77·3* | *78·9* |
| Horizontal circumference, | 503 | 485 | 493 | 503 | 488 | 469 |
| Frontal longitudinal arc, | 129 | 125 | 123 | 129 | 120 | 112 |
| Parietal „ „ | 125 | 118 | 114 | 127 | 119 | 112 |
| Occipital „ „ | 112 | 105 | 115 | 107 | 111 | 106 |
| Total „ „ | 366 | 348 | 352 | 363 | 350 | 330 |
| Vertical transverse arc, | 290 | 292 | 280 | 308 | 300 | 287 |
| Length of foramen magnum, | 40 | 37 | 34 | 32·5 | 30 | 32 |
| Basi-nasal length, | 94 | 98 | 92 | 98 | 98 | 95 |
| Basi-alveolar length, | 95? | 105 | 91? | 97? | 100 | 94 |
| *Gnathic Index*, | *101·* | *107·1* | *98·9* | *98·9* | *102·* | *98·9* |
| Interzygomatic breadth, | 123 | 129 | ... | 128 | ... | ... |
| Intermalar „ | 107 | 117 | 117 | 112 | 112 | 105 |
| Nasio-alveolar length, | 58? | 58 | 56? | 57? | 57 | 61 |
| *Maxillo-facial Index*, | *47·1* | *44·9* | ... | *44·5* | ... | ... |
| Nasal height, | 43 | 42 | 44 | 46 | 44 | 47 |
| Nasal width, | 28 | 29 | 27 | 26·5 | 26 | 27 |
| *Nasal Index*, | *65·1* | *69·* | *61·4* | *57·6* | *59·* | *57·4* |
| Orbital width, | 40 | 43 | 37 | 38 | 40 | 40 |
| Orbital height, | 33 | 30 | 29·5 | 31 | 30 | 30·5 |
| *Orbital Index*, | *82·5* | *69·8* | *78·4* | *81·6* | *75·* | *75·* |
| Palato-maxillary length, | 55 | 59 | 50 | 56 | 55 | 52 |
| Palato-maxillary breadth, | 62 | 65 | 64 | 65 | 63 | 61 |
| *Palato-maxillary Index*, | *112·7* | *110·1* | *128·* | *116·* | *114·5* | *117·3* |
| Length of molars and premolars, | 50 | 40 | 44? | 43 | 42 | 41? |
| *Dental Index*, | *53·1* | *40·8* | *47·8* | *43·8* | *42·8* | *43·1* |

[From the measurements of KNOWLES and FREIRE-MARRECO, recorded in Table II., three of the Oxford skulls are below 75, *i.e.* are dolichocephalic; one at 77·3 is in the lower term (below 77·5) of the mesaticephali, and two are in the upper term of that group; the mean cephalic index of the series is 75. With the exception of No. 2, the height is less than the breadth, and the mean vertical index is 71·8. In the projection of the jaw taken by FLOWER's method, no skull was orthognathous, one was prognathous, the others were mesognathous, and the mean of the series, 101·1, was mesognathous. All the skulls showed a wide platyrhine nose, and the mean nasal index was 61·6;

the mean nasal height was only 44·3 mm. In the dimensions of the orbit the height was small in proportion to the width, and the orbit was low or microseme. The mean palato-maxillary index was 116·6, *i.e.* horseshoe-shaped or brachyuranic.

The three skulls in which the cephalic index was mesaticephalic were shorter in the parieto-occipital region than those with dolichocephalic proportions, and corresponded with the form named by SERGIE *pentagonoides planum*. In each skull the anterior end of the sagittal suture was on the summit of the roof-shaped vault, but further back the suture sank into a mesial depression, bounded on each side by a lateral ridge on the parietal bone. The parietal eminences were distinct, and in some skulls very prominent. A shallow antero-posterior depression was on the parietal between the lateral ridge and the parietal eminence, but in three skulls the depression was not marked in the frontal region.]

*Cranium.*—The characters of the Tasmanian crania in various collections have been described, in some cases with much detail, by G. WILLIAMSON, BARNARD DAVIS, FLOWER, GARSON, TOPINARD, DE QUATREFAGES and HAMY, WIEGER, HARPER and CLARKE, DUCKWORTH, KLAATSCH and myself, and several of the skulls have been figured. The crania in the museums in Paris have formed the subject of elaborate descriptions by M. TOPINARD, and MM. DE QUATREFAGES and HAMY, who have pointed out their most salient features. The vault, as a rule, was roof-shaped, the sagittal line was keeled, and the vault sloped steeply down to the parietal eminences, which were well-defined, prominent, and at times approximated to a conical form. Raised lines were said to extend from before backwards in the area between the sagittal suture and the parietal eminences, whilst grooves (*gouttières*) extended in the same direction above the parietal eminences to end about the middle of the parietal bones. The frontal eminences were distinct. The supraciliary ridges and glabella were strong and overhung the orbit. The sagittal suture was depressed in a groove in the mesial keel; the vault behind the obelion formed an almost plane surface as it sloped down to the lambda. The occipital pole had not, as a rule, much projection; the inion was feeble, and the suprainial area, in its relation to the cerebrum, was small in proportion to the size of the nuchal or cerebellar part. Some, if not all, of these characters were recognised by BARNARD DAVIS, FLOWER, and GARSON, in the skulls in the important collection in the Museum of the Royal College of Surgeons, and by HARPER and CLARKE in those in the Hobart Museum. In my account of the skulls in the Edinburgh museums, I have emphasised these characters as diagnostic of the vault of Tasmanian crania, and I have expressed their importance in the description and by the figure (page 369) and in the Plates I., II.

The measurements published by myself and the authorities referred to enable one to state the range in the dimensions of length, breadth, and height of the crania and the proportion which these diameters bear to each other. As regards length, five male skulls were said to be 190 mm., or even a little more in the longest diameter, but the greater number were between 180 and 190 mm., and several were between 170 and 180 mm. In the greatest breadth, eleven males were 140 mm. or a little more, but the majority were between 130 and 140 mm. The basi-bregmatic height gave a maximum 142 mm., but from 130 to 140 mm. was the rule; the female skulls measured

were less than 130 mm., and one has been recorded as low as 117 mm. The female Tasmanian skulls, as in other races, were less in height than the males. In their external dimensions the crania were, as a rule, moderate in size.

The length-breadth or cephalic index I have computed in sixty-nine Tasmanian skulls. The lowest recorded is 69·1, in the male skull (xxx. 6) in the University of Edinburgh; the highest 79·9, in a skull (No. 1105) in the Hunterian Collection in the Royal College of Surgeons of England. The mean index in sixteen adults in the latter museum is 76·1, for FLOWER, differing from anthropologists generally, measured the length from the ophryon to the occipital point, and excluded the glabella, so prominent in Tasmanian crania; had this been included, the individual as well as the mean index would not have been so high, and more in accordance with my own and other measurements. The mean index of the sixty-nine skulls was 74·7, and of these thirty-eight were 75 or less (dolichocephalic), nineteen were between 75·1 and 77·5, *i.e.* in the lower term of the mesaticephali, approximating therefore to the dolichocephali; twelve were in the higher term of the mesaticephali, and no specimen was brachycephalic, *i.e.* numerically, 80 or upwards. As about five-sixths of the crania were numerically dolichocephalic or closely approximated thereto, one is justified in regarding this as the group with which the Tasmanian aborigines may be associated. With regard to the minority in the higher term of the mesaticephalic group, seeing that the specimens in museums had been presented by various collectors, many of whom had had no special training in discriminating characters, it is not unlikely that some skulls have been regarded as those of Tasmanian aborigines which may have been half-castes, especially if obtained after the English occupation of the island. It is also possible that two or three skulls of Polynesian islanders may have got accidentally mixed with the Tasmanians and have been wrongly labelled.

In previous memoirs I have considered the relation of length to height in several hundred crania of different races, and I have now computed the length-height or vertical index, not only in eight of the Tasmanian skulls described in this memoir, but in fifty-seven skulls measured by the craniologists in charge of other collections. Of the sixty-five adults, thirty-nine were presumably male and twenty-six female. The vertical index ranged from 66·2 to 80, and the mean was 71·1. In twelve specimens the index was below 70 and may be termed low or chamæcephalic; in forty-two it was from 70 to 75, metriocephalic (orthocephalic); in only six did the index exceed 75, so as to give a high or hypsicephalic character to the cranial vault. The skulls, therefore, in the majority of specimens, were moderately high in relation to the length, as is shown in the mean index, 71·1, computed for the whole series.

In sixty-five skulls the breadth exceeded the height in forty-eight specimens; the breadth was less than the height in twelve, and the breadth and height were equal in five. I have elsewhere* called attention to the fact that in such well-pronounced

* See references in my memoir on the Craniology of the People of Scotland, *Trans. Roy. Soc. Edin.*, vol. xl., part iii. p. 599, 1903.

dolichocephalic races as the Melanesians, the Australians, and the Dravidians, the height of the cranium was, as a rule, greater than the breadth, and the skulls were relatively high and narrow, hypsistenocephalic, in the sense in which the term was employed by Barnard Davis. On the other hand, in characteristic brachycephalic races as the Burmese, Andaman Islanders, and brown Polynesians, the height was usually less than the breadth and the skulls were broad and low. The relations of breadth to height may be expressed by a *breadth-height index* computed by the following formula, the breadth being regarded as $= 100 : \frac{\text{basi-bregmatic height} \times 100}{\text{parieto-squamous breadth}}$.

In eight of the adult skulls in the Edinburgh museums the mean breadth was 132 mm.; the breadth was more than the height in five, but less than the height in three; the mean height was 131 mm., which gave a mean breadth-height index 99·3. When the corresponding dimensions of the Tasmanian skulls measured by other observers were computed along with those which I have now recorded, the mean breadth worked out at 133·8 and the mean height at 128·2, which gave for the series a mean index 95·8. The mean breadth-height index, therefore, in these crania was less than 100, and the skulls belonged to the group which I have elsewhere named platy-chamæcephalic, *i.e.* broad and low crania.* In this respect, notwithstanding the relation of length to breadth being of the dolichocephalic type, that of breadth to height corresponded with the proportion existing in many brachycephalic races. We may conclude that in Tasmanian crania it is the rule for the breadth to exceed the height, a character which is without doubt due to the prominence of the parietal eminences.

The internal capacity of my seven adult male crania ranged from 1100 to 1430 c.c., with the mean 1235 c.c. In the males in the Paris museums De Quatrefages and Hamy gave approximately 1465 c.c.† for two, and 1375 c.c. for three specimens. In Flower's series the range of nine males was from 1100 to 1400 c.c., with the mean 1243; in Harper and Clarke's three males the range was from 1155 to 1450 c.c., with the mean 1282; in the Oxford collection two males were respectively 1180 and 1220 c.c.; Wieger stated that the skull in the Breslau Museum measured 1225 c.c., and Duckworth gave the capacity of the male skull (No. 2096) in the Cambridge Museum as 1130 c.c. The general result of these measurements shows that the average capacity of the male Tasmanian skull is from 1200 to 1300 c.c., though a few individuals may have an exceptional capacity of more than 1400 c.c., and the mean of the three largest was as much as 1448 c.c., which approaches the mean capacity in European men. Barnard Davis determined the capacity of the skulls in his collection by filling them with sand, which he then weighed and expressed the amount in ounces avoirdupois and in grammes. In his memoir on the determination of the weight of the brain,‡ he has

* Memoir on Scottish Crania, *op. cit.*

† These authors employed the method of Broca to obtain the internal capacity, a method which it is now admitted overestimates the amount of the cranial contents.

‡ *Phil. Trans. Roy. Soc.*, London, 1868.

given the mean internal capacity also in cubic inches. He stated the mean of eleven Tasmanian skulls, seven males and four females, to be 1197 grammes, equal to 82·8 cubic inches; as the mean capacity in the males is put at 1230 grammes, the equivalent would be 1392 c.c., which is materially higher than the average amount obtained by myself and the other observers above referred to. The higher average is probably due to the fact that the sand which filled the male skull (No. 1761) is said to have weighed 83 oz. avoir., equalling 2355 grammes, which, when expressed in cubic centimetres, gives an abnormal capacity.

In the Tasmanians, as in other races, the mean capacity of the female crania is distinctly below that of the males. I had only one female skull, which measured 1260 c.c.; De Quatrefages and Hamy found three skulls in the Paris museums to have a mean capacity 1170 c.c. In Flower's series the range in seven crania was from 1075 to 1350 c.c., with the mean 1175 c.c.; in Harper and Clarke's series five skulls ranged from 1050 to 1135, with the mean 1089; four specimens in the Oxford collection ranged from 1060 to 1200, with the mean of 1135 c.c. Barnard Davis gave in his memoir the mean capacity of four females as 1100 grammes; but in his work on the osteology of the Tasmanians he places it as 1103 c.c. In both sexes, therefore, the mean is markedly below the European standard, and the skulls as regards their capacity fall into the microcephalic group.

*Face.*—The configuration and proportions of the face as they have been described in the specimens under review may now be considered. The projection and mass of the glabella and supraciliary ridges and the deep depression of the nasion constituted marked characters. The nasal bones were short and narrow. The bridge of the nose was feeble and the profile outline was strongly concave. The anterior nares were wide absolutely, and also relatively to the height of the nose, which was short; the nasal index in fifty specimens measured ranged from 49·1 to 69, and the mean was 58·8, markedly platyrhine. The nasio-alveolar diameter, which corresponded with the length of the superior maxillæ, was short, which occasioned the short, vertical diameter of the face as a whole, the short nose, as well as the low vertical diameter of the orbits; though the massive supraciliary ridges and superior orbital borders contributed also to diminish the height of these chambers. The orbital index in fifty-one specimens ranged from 66·7 to 91·9, and the mean was 77·8, which established a low orbital, or microseme index for the Tasmanian skulls.

The forward projection of the upper jaw varied in the individual specimens, and the eye could recognise some in which the orthognathic character was evident; several were prognathic, and others were intermediate in the degree of projection. When the degree of projection was estimated by the proportion between the basi-nasal and basi-alveolar diameters, the former being regarded as = 100, and an alveolar or gnathic index computed according to the method of Flower, the index in thirty-four specimens, recorded by different observers, ranged from 96·9 to 113·2, and the mean of the series was 103·6, prognathic, therefore in accordance with Flower's classification.

Objections have, however, been advanced from time to time to the plan which he pursued, and consequently to the results obtained, and his method has recently been criticised with much force by Professor ARTHUR THOMSON and Mr RANDALL-MACIVER, by whom another method of estimating prognathism has been suggested and a trigonometer devised for obtaining it.* The Tasmanian skulls in the Oxford collection have been tested by Miss FREIRE-MARRECO with the trigonometer, as well as by FLOWER's method, and a facial angle has been also obtained. The method of FLOWER resulted in no skull, apparently, being orthognathic, whilst one fell into the prognathic group and the rest were mesognathic, of which two were in the higher terms of that group. As measured by THOMSON's trigonometer, two of these skulls were prognathic, two were in the higher terms of the mesognathic group, and two were orthognathic. The facial angle in the Oxford collection ranged from 68° to 76°, and the projection in accordance with the standard of the Frankfort agreement was prognathous. The different results procured by these methods on the same skulls illustrate the difficulty of obtaining a precise estimate of the degree of prognathism.

The incisor teeth had not been artificially extracted in any of my specimens. In a male Tasmanian skeleton from Flinders Island, in the Museum of the Royal College of Surgeons, FLOWER thought that the two upper central incisors had been removed during life, and similarly that in a female skeleton the four upper incisors had been extracted. BARNARD DAVIS considered that there could be no doubt that the teeth in these skulls had been punched out, as is the practice with some Australian tribes, and as is common amongst the Sandwich Islanders, for the alveolar process was absorbed and wholly effaced. In no other collection has a similar condition been described, so that the practice of extracting the incisors during life was exceptional. LA BILLARDIÈRE, who saw in 1793 more than forty natives, stated that of the people of Adventure Bay in some the upper middle incisor and in others both upper incisors were wanting (p. 320). He seems to be the only naturalist who has recorded this condition in the living native.

Several observers had noticed the large size of the teeth in the Tasmanians. FLOWER, in his paper "On the Size of the Teeth as a Character of Race," † placed them along with the Melanesians and Australians in the *Megadont* group, and he gave the mean dental index in the Tasmanians in both sexes as 48·1, whilst that of the Australians was 45·5. He had elsewhere stated ‡ that they seemed to differ from these and other kindred races in the tardy development and irregular position of the posterior molars, which are frequently retained within the alveoli, or are set obliquely or irregularly, as if owing to their large size they could not find room in the jaw. The specimens in the Edinburgh museums do not, however, show irregularities or tardy development in the molar series.

* *The Ancient Races of the Thebaid*, Oxford, 1905.

† *Journal Anthropological Inst.*, November 1884.

‡ Evening Lecture, *Proceedings* Royal Institution of Great Britain, May 31, 1878.

In a previous memoir* I made a comparison between the upper and lower dentary arcades in Australian skulls, as regards their overlapping and the length and width of the crowns of the premolar and molar series of teeth, to which I may refer for particulars. In the group of Tasmanian skulls the conditions did not permit of a similar detailed examination and the computing of a dental index after the manner of FLOWER. In Table II., p. 375, compiled by KNOWLES and FREIRE-MARRECO from their measurements of the skulls in the Oxford University Museum, the length of the premolars and molars in the upper dentary arcade is given and a dental index has been computed, which ranges from 40·8 to 53·1, with a mean of 45·2, which almost corresponds with the mean of the Australians recorded by FLOWER. KLAATSCH'S measurements also show large molars in a Tasmanian skull which he examined.

## COMPARISON OF TASMANIANS WITH OTHER RACES.

Van Diemen's Land was discovered in 1642 by the Dutch seaman ABEL JANSEN TASMAN, but the name which he gave to the island is now replaced by that of Tasman himself. He observed smoke and heard the sound of people, but made no observations on the inhabitants.

The first description of the natives was written by M. CROZET, lieutenant in Marion du Fresne's ship *Mascarin*,† which anchored in Frederick Henry Bay, in the south of the island, in 1772. They were of ordinary stature, one man being 5 ft. 3 in.; the skin was black, but when washed it was said to be reddish brown, though smoke and dirt made it look dark. The hair was woolly, tied in peppercorn knots and powdered with red ochre; the mouth was full, teeth very white; the nose was flattened; the eyes were generally small and bilious-looking; the men were not circumcised, but some had cicatrices on the skin.

Five years later the great navigator JAMES COOK anchored in January 1777 in Adventure Bay, in the south of the island.‡ The men were naked, but the women wore a kangaroo skin tied over the shoulders and round the waist. The colour was black, and the skin was marked with scars. The hair of the head was woolly, though in the women it was often completely or partially shorn; it and the beard, as well as the face, were smeared with red; the lips were said to be not remarkably thick, nor the nose flat. Mr WM. ANDERSON, surgeon to Captain Cook's ship, *Resolution*, supplemented the above description: the skin, he said, was a dull black, the colour being heightened by smutting the body; the hair was perfectly woolly and divided into small parcels by grease and red ochre, though in a boy whose head had not been smeared the hair was of the same kind; the nose was not flat, but broad and full; the lower part of the face projected; the teeth were broad but not equal, and the mouth was rather wide. A drawing by

* *Journ. of Anat. and Phys.*, vol. xxv. p. 416, 1891.
† LING ROTH'S translation of CROZET'S *Voyage*, p. 18.
‡ *Third Voyage to the Pacific Ocean*, vol. i. p. 95, London, 1785.

Webber, artist to the expedition, of a man, and of a woman with the head shaved, illustrated Cook's description.

The island was visited in 1788 by Captain Bligh, who saw a few natives, moderate in stature, and with the skin a dull black and marked with scars. In 1792, and again in 1793, Admiral d'Entrecasteaux stayed some time on the coast. In 1798 the wide strait which separates Tasmania from Australia was discovered by the naval surgeon George Bass, and he and Captain Flinders surveyed the coasts in that and the years immediately following.* They met a man and two women at the mouth of the Derwent whose hair, either close-cropped or naturally short, did not, they said, appear to be woolly. Their skin was marked with cicatrices, and the face was blackened. Colonel Collins in his account of New South Wales† includes in it, extracted apparently from Bass's *Journal*, a chapter on Tasmania in which is a similar description of the natives; but in a footnote he stated that hair undoubtedly woolly had been cut from the head of a native seen by Mr Raven at Adventure Bay. In 1802 Captain Baudin spent some time on the island. In 1803 Tasmania was added to the British Empire, and in the following year a convict establishment was settled at Hobart.

D'Entrecasteaux was accompanied by the naturalist La Billardière, who described‡ the natives as tall and muscular, with curled hair and long beards; he also figured two men, a boy, and a woman carrying a child on her head, as well as groups pursuing their avocations. The woolly, frizzled hair and the general aspect of the features were depicted. The skin, he said, was not a very deep black, but the colour was deepened by rubbing it with charcoal, and it was marked with cicatrices.

M. Péron, the naturalist on Captain Baudin's ship, enjoyed good opportunities of observing the external characters, muscular power, habits and manners of the natives. The women greased the skin with the fat of seals and daubed it with charcoal, its natural colour was more brown than in the Australians and it was marked with scars. They were naked, though some wore a kangaroo skin on the back. The hair was short, frizzled, black, and in some reddened with ochre.§ Péron published an Atlas with several portraits in which the characters of the hair and features were represented; the mammæ were pendulous, the limbs feeble, the belly large.

Captain Dumont d'Urville, in his first voyage in *L'Astrolabe*, 1826-29, and in the second voyage with *L'Astrolabe* and *La Zélée*, 1837–40, spent some time on the south coast of Tasmania. The naturalists to the first voyage, MM. Quoy and Gaimard, said the natives‖ had short, woolly hair, though the women frequently shaved the head; the skin was black, but the nose was not so flattened and the lips were not so thick and projecting as in the African negro. In the Atlas, a man and woman are figured with characteristic hair and with slender limbs. The black skin, the frizzled

* Flinders, *Voyage*, vol. i. p. 186.
† *Account of the English Colony*, vol. ii. p. 187, London, 1802.
‡ *Voyage in Search of La Perouse*, pp. 127, 295 *et seq.*
§ *Voyage de Découvertes, etc.*, vol. i. pp. 221, 226, 448; Atlas, plates viii. to xii.
‖ Dumont d'Urville, "Voyage de l'Astrolabe," *Zoologie*, vol. i. p. 45, Paris, 1830.

and woolly hair, the frizzled and abundant beard and moustache, were recognised by MM. HOMBRON and JACQUINOT, the naturalists in the second voyage.* DUMOUTIER, in the Anthropological volume,† described the face as massive; the eyes sunken; the nose voluminous, about one-quarter the height of the whole face; the mouth very large, but with moderately thick lips; the teeth large, the skin black, the hair woolly.

In the Atlas to the voyage were represented the busts of six Tasmanians, modelled at Hobart Town under the direction of DUMOUTIER, four from nature and two from previously modelled busts, also three skulls. The natives were from different parts of the island. In two the woolly hair was in ringlets, which covered the forehead and the cheeks; in the others it was short. Figures of two of these busts, showing differences in the length of the hair, have been reproduced by DE QUATREFAGES and HAMY in the *Crania Ethnica*. DUMOUTIER had subsequently the opportunity of studying the head of a native who died at Hobart Town, which was sent to Paris by M. EYDOUX of the corvette *Favorite*. The hair was frizzled, crisp, woolly, short, and very black; the beard black, eyebrows black and thick, eyeslit small, sclerotic yellowish; forehead sloping a little backward, projecting in its middle; parietal regions large, forehead by comparison singularly narrow; nose short, straight, and forming with the forehead a re-entering angle and acute as if broken at its origin; large nares with tip of nose large and rounded; supraciliary ridges very prominent in front of the eyes, which looked small and concealed in the orbits; jaws not specially projecting; lips moderately projecting. The head has been figured by GERVAIS in his work on Zoology and General Palæontology.

G. W. WALKER, who visited in 1832 the native settlement on Flinders Island, described the people as rather below the average stature of the English; complexion very dark, almost black, a few of almost a coppery hue, palms and soles lighter than their bodies; lips generally thick; nostrils flat and distended; hair uniformly black and woolly. BRETON in 1834, LAPLACE in 1835, confirmed the description of the skin, hair and features. R. H. DAVIES recorded in 1846 the customary character of the hair; the bluish-black colour of the skin; the narrow forehead; flat nose; wide nostrils; prominent jaws; wide mouth, large strong teeth. CALDER in 1874 spoke of the hair being plastered with grease and ochre, so that the locks resembled a bundle of painted ropes.

STRZELECKI in his account of Van Diemen's Land has figured an aboriginal man and woman. Portraits of natives were painted by Mr DUTERREAU of Hobart Town, some of which have been reproduced in BONWICK'S *Last of the Tasmanians* and in LING ROTH'S volume. In the majority the hair was represented short and woolly, but in a few of the men it was longer and arranged in short ringlets. Before the last survivors of the race had disappeared photographs were taken by WOOLLEY in 1866,‡ including William Lanné the last man, who died in 1869, and Truganina, the last woman, who died in 1877, which were reproduced in 1871 by GIGLIOLI and subsequently by other writers. They closely corresponded in their facial characters with the excellent description abstracted above

* "Voyage au Pol Sud," *Zoologie*, p. 320, t. i., Paris, 1846. † *Idem*, *Anthropologie*, p. 134, Paris, 1854.

‡ Figured both in BONWICK'S *Last of the Tasmanians* and in LING ROTH'S *Treatise on the Aborigines of Tasmania*.

from DUMOUTIER. In the Museum of the Royal College of Surgeons in Ireland is the head of an aboriginal which has been figured by LING ROTH in his comprehensive work.

The data furnished by so many excellent observers, and extending at intervals over about a century of time, enable us to realise the external physical characters of the aborigines of Tasmania. Though differing in minor details, the descriptions correspond in their main features, which may be summarised as follows:—Skin black or very dark brown, often marked with cicatrices; hair black, frizzled, woolly, usually in short locks, though sometimes forming separate small ringlets, with abundant beard and whiskers; face short in relation to breadth, nose short, sunk at the root, not flattened, nostrils broad and full (Plate I. fig. 1); mouth large, lips moderately thick; eyes small and sunken; eyebrows overhanging; forehead narrow, in the men somewhat retreating; upper jaw somewhat projecting; stature moderate—one man measured 5 ft. 3 in. (CROZET), others seen by PÉRON were 5 ft. 2, 4 or 6 in., and one was said to be 5 ft. 10 in. (1 m. 786 mm.), but he was doubtless exceptional; whilst G. A. ROBINSON gave the measurements of twenty-three men as ranging from 5 ft. 1 in. to 5 ft. $7\frac{1}{2}$ in., and of twenty-nine women from 4 ft. 3 in. to 5 ft. $4\frac{1}{2}$ in. FLOWER stated that the average height of three male skeletons was 5 ft. $3\frac{1}{2}$ in., and that of a female 4 ft. $7\frac{1}{2}$ in. The body was well developed and muscular, especially the buttocks; the limbs were slender, and the belly was proportionally large.

Those who had the opportunity of observing the living natives of Tasmania, naturally compared their appearance with that of other races of aborigines. CROZET considered the hair to be like that of the wool of Kaffirs. COOK stated that it was as woolly as that of any native of Guinea, and Surgeon ANDERSON, who accompanied him, thought that the Tasmanians resembled the natives of Tanna and Mallicollo. PÉRON was of opinion that the Tasmanians were altogether different from the Australians in physical characters. The short, woolly, frizzly hair contrasted with the long, straight hair of the Australians, and the colour of the skin was browner than in the latter. Owing undoubtedly to the skin being smeared with grease and charcoal, its precise natural colour was somewhat difficult to determine. CROZET stated that when washed it was reddish brown; PÉRON, as above stated, regarded it as inclining to brown; whilst such expressions as dull black, bluish black, perfectly black, sooty black, very dark almost black, not a very deep black, occur in the descriptions of other observers. QUOY and GAIMARD considered the Tasmanians as approaching the African negro, though the nose was not so flattened nor the lips so thick and protuberant; they were definitely different, they said, from the natives of South Australia, and still more from the Papuans, with whom they had no relations further than that of colour: they regarded them as a distinct race—an opinion concurred in by MM. HOMBRON and JACQUINOT, who, seeing that they believed in the special origin of the race, did not consider it necessary to inquire into their descent. DUMOUTIER stated that they bore the type of other Melanesians like the Fijians and the natives of New Guinea, but with certain differences; he considered that they should be referred to a negro race: the length of

the forearm and leg, their stature, gait, and the external characters generally, led him to take this view. WALKER in regard to their black, woolly hair held that in many respects they nearly resembled the African negro. DAVIES described the skin as less black than in the African negro, slightly more so than in Lascars, but the lips were not so full as in negroes.

## RACIAL AFFINITIES AND DESCENT OF THE TASMANIANS.

Guided by the descriptions of the aborigines as seen by navigators, by the naturalists of the several expeditions, and by those who lived on the island and observed the natives for some years prior to their extinction, anthropologists have studied the question of the racial relations and descent of the Tasmanians, and have discussed their possible affinities to the Australians, to Negroes, Negritos, and to the Melanesian or black race of the great Pacific Archipelago.

In the discussion of this question special attention has to be paid to the geographical position of Tasmania, which, with the exception of the South Island of New Zealand, is the most southern land in the Oceanic area on which the older navigators met with human inhabitants. Though now separated by Bass's Straits from Australia, evidence of various kinds supports the view that in past times it was continuous with the Australian Continent. Bass's Straits, though varying in width between 100 and 120 miles, is a shallow sea, at the most not much more than 100 fathoms deep, and somewhat comparable in this respect to the North Sea, which now separates Great Britain from the continent of Europe. But in addition groups of islands are found in the Straits which form an imperfect land bridge between Tasmania and Australia. The consideration of the fauna, more especially the Marsupial mammals, supports the view of the previous continuity of the land. The early navigators frequently referred to the women of Tasmania as wearing the skin of the kangaroo on their backs, and the Tasmanian wolf (*Thylacinus cynocephalus*), the largest existing carnivorous marsupial, and the Tasmanian devil (*Sarcophilus ursinus*), though now confined to Tasmania, at one time lived in Australia, where their remains have been found. The Wombats (*Phascolomys*), the Opossum (*Trichosurus*), the Monotremes Ornithorynchus and Echidna are still extant, both in Australia and Tasmania: in these respects, and in others which might be referred to, a strong affinity exists between the fauna in both regions.

In considering the origin of the human inhabitants we may put on one side the possibility of a special creation of the Tasmanians, though the naturalists who accompanied the expeditions of DUMONT D'URVILLE seemed to have favoured the hypothesis that they were a distinct species of man. There remains, therefore, the theory that the aborigines of Tasmania were descended from immigrants from other parts, and as the islands to the south were not populated, the migration would necessarily have been from the north.

The migrations of men for a long distance by land is a question of time and food supply, and if the impedimenta of travel are bulky and numerous, beasts of burden or other aids to locomotion are required. If migration takes place on water, properly constructed and sufficiently large craft for conveying man and his impedimenta are necessary. As the Tasmanians lived on an island it is important to inquire if they, and presumably their ancestors, were a seafaring people. The statement has sometimes been made that the natives had no canoes or other navigable craft, but this was not strictly in accordance with the evidence. For example, La Billardière figured (pl. 46) and Péron described and figured (pl. xiv.) canoes on the south and west coasts made of rolls or strips of bark and bound together by thongs of reeds or grass, which could hold from two to four or five people. Dumont d'Urville saw a raft or catamaran formed of two trunks of trees connected by transverse pieces, which could carry ten people and be propelled by long poles. Craft as above described were used on the rivers, to cross the mouths of the bays which indent the coast, or the narrow channels which separate the mainland from the small islands near the coast, but they would seem too fragile to contend against the strong winds and currents of the Straits of Bass. Bark canoes and rafts somewhat similar in character were also in use amongst the natives of the south and east coasts of Australia. In North Australia, however, where the natives were under the influence of the islanders in Torres Straits and the Papuans of New Guinea, canoes fifty feet long formed by hollowing out the trunk of the cotton tree, capable of holding twelve or fifteen persons and propelled by short paddles, or even a sail formed of palm leaves, were employed.* If Tasmania had been colonised originally by the people of New Guinea or other Oceanic islands, the art of constructing capacious seagoing canoes does not seem to have been transmitted by them to their descendants. But if colonised from Australia, the migration of man had without doubt taken place before the formation of Bass's Straits, along the surface of continuous land, which also served for the passage of the marsupial mammals common to both countries.

The comparison of the physical characters of the aborigines of Australia with the Tasmanians appropriately forms a subject of consideration. With scarcely an exception the early navigators recognised important differences in their external characters; similar opinions have been expressed by later observers, and the conclusion has been reached that the existing natives of Australia are distinct from the Tasmanians. In the Australians the hair is black, fairly long, wavy or almost straight; its shaft is ovoid, relatively thick and not flattened as is the case with the short, woolly, frizzled, finer hair of the Tasmanians, in whom the hair, though sometimes stained red with ochre or even bleached with lime, is usually described as black, though Sydney Hickson has recently stated that it "is of a light golden-brown colour."† Well-formed beard and moustache were found both in Tasmanians and Australians. In the Australians the skin is a

* Chapter on Canoes in Brough Smyth's work on the *Aborigines of Australia*, p. 407, vol. i.

† See description in Ling Roth's treatise, p. 226. Is it not likely that Professor Hickson's specimen had been taken from hair that had been bleached?

chocolate-brown colour, though varying in its depth of tint; in the Tasmanians it was more definitely black, though from the recorded descriptions it varied in shade of colour. In the Australians the upper jaw was more prognathic, the lips were thicker, and the teeth were larger and stronger than in the Tasmanians.

As the skull furnishes important criteria for discriminating the physical characters of races, I purpose, in the next place, to institute a comparison between the skulls of the Tasmanians and those of the Australians and the other races in the Pacific area with which they have been compared. I have made use for this purpose of the representative collection of skulls in the Anatomical Museum of the University, for the most part formed during my tenure of office in the chair of Anatomy, and to which valuable additions have subsequently been made by my successor Professor CUNNINGHAM.

In my memoir "On Human Crania" in the "*Challenger*" *Reports* * I described the characters of forty-nine Australian skulls then in the Anatomical Museum, and compared them with the descriptions by BARNARD DAVIS, FLOWER, DE QUATREFAGES and HAMY, of the skulls in their collections.

The cranial vault in the Australians is strongly roof-shaped, though in some specimens from South Australia it is more flattened at the vertex. The parietal eminences are not specially prominent; the side walls approach the vertical; the crania are unusually long, the mean glabello-occipital diameter of twenty-three adult males being 191·6 mm.; they are relatively narrow in relation to the length, and the mean parieto-squamous breadth is 132 mm., which yields a cephalic index 68·8. The male crania, in the mean, are hyper-dolichocephalic; so that if one were to see a skull in a collection catalogued Australian, one would doubt the accuracy of its identification, if the cephalic index computed from the maximum length and breadth was in the higher or even the middle term of the mesaticephalic group. It is unnecessary for me to enter again into an examination of the relative breadth and height of the Australian crania, as they have been so fully detailed in my "*Challenger*" *Report*. It may be sufficient to state that from an analysis of one hundred and fifty crania in both sexes, in which these diameters were taken either by myself or by previous observers, the height was less than the breadth in fifty-one, these dimensions were equal in fifteen, and the height was greater than the breadth in eighty-five. Owing to the importance attached by TOPINARD, DE QUATREFAGES and HAMY to the special characters of the cranial vault in the Tasmanians, on which I have dwelt in my description of the skulls in the Edinburgh and other Museums, pp. 368, 376, I have re-examined the vault in sixty-one Australian skulls now in the University Museum. In forty-four from Queensland, New South Wales and Victoria, an antero-posterior depression on the parietal bone was only faintly indicated in a small minority, and scarcely perceptible on the frontal bone; whilst a sinking of the hinder part of the sagittal suture between a pair of feeble lateral ridges was only occasionally present. In nine skulls from South Australia four showed a parieto-frontal

* Part xxix., 1884; and part xlvii., 1886.

depression and three had the sagittal suture sunk behind between a pair of lateral ridges; whilst of eight skulls from West Australia five possessed similar features.

In the Australians the glabella and supraciliary ridges were usually more strongly marked than in the Tasmanians; the forehead was more receding; the upper jaw was more prognathous and in many Australian skulls the line of demarcation between the floor of the nose and the incisive region had almost or entirely disappeared, so that the nasal floor was directly continued into the incisive area of the maxilla; the roof of the mouth was more elongated, dolichuranic, and the premolar and molar borders of the two superior maxillæ were approximately parallel to each other; the lower jaw was stronger and the chin was more pronounced. In both races the skulls were phænozygous, platyrhine, microseme, and microcephalic in their internal capacity.

From the consideration of these characters the skulls support the opinion, based on the study by so many observers of the external features, that the existing aborigines of Australia are distinct from the Tasmanians, although the presence, in a proportion of the natives of South and West Australia, of skulls in which the height was less than the breadth, the not unfrequent sunk sagittal suture, the more marked parietal eminences, and the antero-posterior parietal depressions, point to a possible amount of intermixture and racial affinity of these Australian tribes with the Tasmanians.

Topinard, in his *Étude sur les Race Indigènes de l'Australie*, came to the conclusion that in some parts of Australia, in addition to the general body of aborigines, tribes existed with woolly hair, black skins, short stature, small round skulls, very prognathic jaws, generally speaking with Negro characters, distinct in features from the recognised Australian type, and inferior in intelligence. The woolly-haired race, he thought, preceded the more straight-haired taller natives, and, probably when displaced by them, took refuge, in part at least, in Tasmania. Topinard therefore inferred that, when the displacement occurred, whilst reasons could be given for regarding the Tasmanians as the remains of an autochthonous race, originally pure and distinct from its neighbours, others equally valid might be alleged for their multiple origin as a cross between a black autochthonous race and one of the invading groups of the great Polynesian family. But whatever may be thought of the descent of the Tasmanians from a woolly-haired Australian autochthone, there does not seem to be satisfactory evidence of the presence in that great country of woolly-haired tribes at the present time, or since Australia became known to Europeans. The balance of opinion is indeed in favour of the view that throughout Australia the present natives generally conform to one pattern in features, colour, and mental character; though possibly on the coast, local infusion of Papuan, Polynesian or Malay blood may from time to time have been introduced amongst them. Indeed, as Giglioli has suggested, the idea of an existing woolly-haired race in Australia is probably due to the loose way in which the terms woolly and crisp have been used by explorers who were not anthropologists.

The aborigines of Australia as known to the British colonists present in their affinities and descent, equally with the aborigines of Tasmania, an ethnological problem. They

have racial characters which distinguish them from the dolichocephalic, mop-haired, black-skinned Papuans and Melanesians; from the brachycephalic, brown-skinned Polynesians; from the brachycephalic, straight black-haired, yellow-skinned Malays; and from the brachycephalic, woolly-haired, black-skinned, dwarf-like Negritos. Whilst in the great islands of Malaya various tribes, collectively termed Indonesians, are found, with skins brown in colour, varying in depth of tint to almost black, long, straight black hair, stature from 5 ft. 2 in. to 5 ft. 4 in; with the head and skull dolichocephalic or approximating thereto; the mean height and breadth of the skull almost equal; the glabella and supraciliary ridges moderate; the nose moderately wide at the nostrils; the face moderate in height and width, the upper jaw not very projecting; the orbits tending to be rounded in form, and the hard palate with a wide and shallow arch,*—characters which collectively distinguish them from the Australians.

Crozet considered the hair of the Tasmanians to be like the "wool" of Kaffirs, and Captain Cook compared it with that of the West African Negro. In most other respects the physical and other differences are marked, and as Africa is separated from Tasmania by a wide and deep ocean, migration from one country to the other in the early stages of human history seems to have been impossible.

In New Guinea and many other Oceanic islands, and in the extensive range of Asiatic islands reaching westwards to the Indian Ocean, people with black skins and other negro characters are found. Sometimes they are spoken of collectively as Negritos, and the term Negritic by some ethnologists has been made to include even the black Dravidian people of Southern India. In my judgment, however, the extension of the term is unfortunate, as it would embrace races which, although they resemble each other in the colour of the skin, differ greatly in many other respects.

The term Negrito should be limited to such black-skinned, woolly-haired people with small brachycephalic heads, jaws not very projecting, nose not so flattened, nostrils not so wide as in the Negro, and of dwarf-like stature, characteristic of the people who under the name Semangs inhabit the Malay Peninsula, or as the Mincopies occupy the Andaman Islands, and as the Aetas are found in some of the Philippine Islands.

It is not impossible that a migration of the Negritos eastwards into the Oceanic area may have taken place in bygone time. It was shown by G. W. Earl in 1845, and subsequently by A. R. Wallace, that only a shallow sea from 40 to 100 fathoms deep, which indicated a recent land connection, separated the Malay Peninsula from the great islands Sumatra, Borneo, Java, which extended northwards towards the Philippine Islands, and that similar shallow straits lie between New Guinea, the islands in Torres Straits, and Australia. It would seem, therefore, that Asia and Australia at one time had been connected with each other through the chain of islands. A. R. Wallace came to the conclusion that a band of deeper sea between Borneo and Celebes divided the islands into two groups—a western Indo-Malayan, the natural productions in which resembled those

* See my Memoir on the Craniology of the Natives of Borneo, etc., in *Trans. Roy. Soc. Edin.*, vol. xlv., part iii., 1907.

of Asia, and an eastern Austro-Malayan, the productions in which corresponded with those of New Guinea and Australia.

On the supposition that a Negrito population, instead of being limited as at present to a few widely separated localities, had formerly been generally distributed throughout Malaya, a migration eastward by land, before it subsided at the shallow straits, was within the limitations of travel. It is also said that the Andaman islanders have canoes hollowed out of single trees, and are expert in their management. If this were general with those Negritos, who lived in proximity to the sea, migration across the narrow intervening straits was within the power of these people.

The inhabitants of New Guinea are the Papuans, and a similar black-skinned race, known generally as Melanesians, occupies groups of islands to the east and north of New Guinea. In their external characters they are distinguished from the Negritos by much longer hair, frizzled at the free end, which may either be arranged as a mop around the head, or be divided into locks which hang down on the shoulders, or be sometimes tied together to form a top knot on the head; the beard also is well developed. They are taller than the Negritos, and are superior to them, both physically and intellectually.

Some years ago I described a number of Papuan crania from New Guinea, and reviewed the literature of the subject.*

The University Museum contains twenty-three skulls which, with one or two exceptions, were collected on the south and the east end of the island. Sixteen had the cephalic index 75 or less, with the mean index 70·8, strongly therefore dolichocephalic; three were mesaticephalic, and four were brachycephalic, the wider skulls being perhaps due to an intermixture with Malay or Polynesian immigrants. The dolichocephalic crania were relatively narrow; the glabella and supraciliary ridges were moderately projecting; the nasion was not greatly depressed; the parietal eminences were not strongly projecting; the cranial vault in some was roof-shaped, but the longitudinal fronto-parietal depression, so characteristic in the Tasmanians, was only feebly indicated in a small minority of the skulls. In six of the crania a shallow depression of the sagittal suture in the postero-parietal region was also apparent. Although in the majority of the Papuan dolichocephali the basi-bregmatic height exceeded the greatest breadth, in some others the height was a little less than the breadth. The mean vertical index of these skulls was 73·2. In the dolichocephalic form and proportions, in the height being usually greater than the breadth, and in the dominancy of the parietal longitudinal arc over the frontal and occipital arcs, the skulls showed Melanesian characters. It is doubtful if short, woolly-haired Negrito tribes, as defined in a previous paragraph, at present exist in New Guinea.

The islands of the Admiralty group are inhabited by Melanesians with black-brown skins and mop-like hair. The museum contains twelve skulls collected by the "*Challenger*." † Each cranium was dolichocephalic, and the mean cephalic index was 70.

* "*Challenger*" *Reports*, p. 81, part xxix., 1884; and *Proc. Roy. Soc. Edin.*, p. 553, vol. xxii., 1900.

† Described by me in "*Challenger*" *Reports*, part xxix., 1884.

With three exceptions the height was greater than the breadth, and the mean vertical index was 72. The glabella, supraciliary ridges and parietal eminences, though distinct, were not specially prominent; the nasion was not greatly depressed; the cranial vault was roof-shaped, but the fronto-parietal longitudinal depression was only faintly indicated in a few specimens. Two skulls of this group showed indications of a depressed sagittal suture in the postero-parietal region.

The natives of the Fiji islands to the north-east of New Guinea have as a rule marked Melanesian features. Their crania have been carefully described by several anthropologists. Although a proportion of the skulls, collected on the sea-coast, possesses mesaticephalic or occasionally brachycephalic proportions, where a Polynesian brachycephalic intermixture is probable, the natives of the interior, as FLOWER has shown, are strongly dolichocephalic. The crania are long, narrow, and high, as in the hypsistenocephalic group of BARNARD DAVIS. Five crania are in the University Museum, two of which are hyperdolichocephalic (C. Ix. 66·8 and 65·7), with the basi-bregmatic height much exceeding the greatest breadth; one is mesaticephalic (C. Ix. 76·4), with a vertical index 77·5, and two are brachycephalic (C. Ix. 81·9, 82·4), in one of which the height is greater and in the other less than the breadth. In these skulls the sagittal suture was not depressed, and only faint indications of a longitudinal fronto-parietal depression were seen.

The New Caledonian group of islands constitutes the most southerly land occupied by people of a well-marked Melanesian type. Their crania have been described by several French and British anthropologists, and most recently by Dr DAVID WATERSTON, the measurements of many of which he has kindly supplied me with from a collection in the University Museum presented by Dr W. RAMSAY SMITH. Fourteen skulls in the museum are characteristically Melanesian, long, narrow, and high, the vault roof-shaped, and the parietal eminences not prominent. In three of the skulls an antero-posterior depression in the parietal region extended, though faintly marked, on to the frontal. In three skulls the sagittal suture was depressed in the post-parietal region. In six males the glabella and supraciliaries were prominent, and the nasion was depressed. Except in one with C. Ix. 77, the skulls were dolichocephalic; the mean cephalic index was 70·1, and as the mean vertical index was 73, the skulls were hypsistenocephalic. The mean nasal height was 47·3 mm., the nasal index in two was leptorhine, in six mesorhine, and in six platyrhine, the mean index of the series being 52·9, scarcely platyrhine. In five skulls the orbits were low with a microseme index, in seven the orbits were rounded at the aperture, and in them the index ranged from 89·7 to 97·3, *i.e.* megaseme. The mean orbital index of the series was mesoseme, 86·1.

Professor HUXLEY, in his writings on the Distribution of Mankind, advocated the view that the Negrito type spread eastwards from Asia into New Guinea, the New Hebrides, the Solomon Islands, the Fijis and New Caledonia. From New Caledonia they migrated southwards to Tasmania, in all probability by intermediate land, which he thought might have been islands now submerged, separated from

each other by short sea passages, though an extension eastward of the present Australian continent would also have supplied a land route.

New Caledonia was thus regarded as almost the limit of the eastward migration of the Negritos, and also as the centre from which the Tasmanian migration started; and it will consequently be interesting to compare the crania of the New Caledonians with the Asiatic Negritos on the one hand, and with the Tasmanians on the other. One can scarcely conceive a greater cranial contrast than is presented by the skull of an Andaman Island Negrito and that of a New Caledonian Melanesian.

The University Museum contains eight skulls from the Andaman Islands. In the Andaman Negrito the skull is small, rounded, brachycephalic (mean C. Ix. 81·5); broad in the parietal region owing to the prominent eminences: the basi-bregmatic height is distinctly less than the greatest breadth (mean V. Ix. 75·7); the vault of the cranium is neither keeled, nor roof-shaped, nor marked by a longitudinal fronto-parietal depression on each side, but is somewhat flattened and with a low transverse arc; the skulls are cryptozygous. The forehead is smooth, and not retreating, with feeble glabella and supraciliaries, but with distinct frontal eminences; the nasion is not depressed, the nose is not broad and flattened; the nasal index is usually platyrhine; the orbits are moderately high in relation to the width, the index being mesoseme; the projection of the upper jaw is moderate, the facial profile is almost straight; the cranial capacity is small.* In the postero-parietal region a broad, shallow, median, depressed area exists, bounded laterally by a low ridge on the parietal bone, and along the middle of this depression the sagittal suture lies sunk below the general plane of the vault.

The New Caledonian skulls, on the other hand, are much longer, and relatively narrower, markedly dolichocephalic (mean C. Ix. 70·1); the height is greater than the breadth (mean V. Ix. 73); the vault is roof-shaped; the skull is usually phænozygous; in the males the glabella and supraciliaries are strong, the frontal eminences are not prominent, the forehead is retreating; the jaws are generally prognathic and the facial profile is oblique. The Andaman Negrito and the New Caledonian are not unlike in the proportion of the height to the width of the nose, and the dimensions of their orbits give a mesoseme index. Both as regards capacity are microcephalic. But the short, black, woolly hair of the Andaman islander and his dwarf-like stature, 4 ft. 8 in. to 5 ft. in the men, contrast with the longer black hair, frizzled at the free ends and capable of being dressed into a mop-like mass, and with the stature, 5 ft. 5 or 6 inches, of the New Caledonian. If the assumption be correct that the New Caledonian is of Negrito descent, it will have to be admitted that a remarkable modification, both in external characters and in skull form, must have taken place since the Asiatic Negrito was transplanted to an Oceanic habitat; and it would, I think, be difficult to advance a sufficient reason from the influence of climate, food, altitude, or other factors in the

* See W. H. Flower's Memoirs, *Journ. Anthrop. Inst.*, November 1879 and November 1884. Also my description in *Trans. Roy. Soc. Edin.*, vol. xl. p. 113, 1901.

environment, to account for the origin of physical differences, which have conferred on these people such marked racial distinctions as we recognise to exist between them.

If we now proceed to the comparison of the aboriginal Tasmanian with the New Caledonian, interesting points are to be noted. They agreed generally as to stature and the colour of the skin, but in the Tasmanian the hair was short and woolly, not long and mop-like. The Tasmanian skull was not strongly dolichocephalic, for though the majority had the cephalic index either below 75 or in the lower term of the mesaticephali, in about one-sixth the index was in the higher mesaticephalic group, and the mean index in sixty-nine skulls was 74·7, the greater relative breadth in the Tasmanian being due to the prominent parietal eminences. The Tasmanian skulls did not show the almost uniform excess of height over breadth which was seen in the New Caledonians, and which gave to the latter a high rank in the hypsistenocephalic Melanesians. On the contrary, in the Tasmanians the height was usually less than the breadth, and the skulls generally were broad, low skulls, platychamæcephalic. The cranial vault was roof-shaped in both, but the New Caledonian did not show the fronto-parietal longitudinal depression so frequently, or to such a degree, as the Tasmanian, neither was the depression of the sagittal suture in the post-parietal region so often seen. The nose was shorter and with broader nostrils, the orbits were lower, the upper orbital region was more massive, the upper jaw was scarcely so prognathous and the lower jaw was not so strong in the Tasmanian as in the New Caledonian. The forehead, glabella, and supraciliary ridges were not unlike in both series. The skulls of the New Caledonians approximated more in their characters to the Australians than to the Tasmanians, though distinguishable from both.

These differences lead one to think that the Tasmanian was not in direct descent from the Melanesians as we know them at the present day. In important respects his physical characters were more nearly allied to the Asiatic Negritos. Though the Tasmanian skull as a rule has a dolichocephalic length-breadth index, yet in the mean 74·7 it approaches the mesaticephalic group. In both the parietal eminences are prominent, the basi-bregmatic height is less than the greatest breadth, the sagittal suture is often depressed below the general plane of the vault of the cranium, and in these respects the skulls approximate to the platychamæcephalic cranial type of the Negrito, and the woolly hair of the one is comparable with that of the other. In stature, however, the Tasmanian was not a dwarf.

The whole question of the descent of the Tasmanians is one of great complexity and difficulty, which has been much discussed by ethnologists. Huxley considered them to be the Negrito modification of the great Negroid type or division of mankind, which had migrated eastwards to New Caledonia and subsequently southwards to Tasmania. Topinard, whilst of opinion that they were the remains of an autochthonous race, recognised that they might be a cross between it and an invading member of the Polynesian family. Barnard Davis regarded them as a peculiar and distinct race, dwelling in their own island. De Quatrefages and Hamy said that, owing to their special characters, they had no affinities with any other race, and that they formed a

distinct subdivision of the black races. FLOWER thought them to be aberrant members of the Melanesian group modified from the original type. LING ROTH considered that the physical characters, manners, customs, mental qualities and language of the Tasmanians supported the theory that they were the aboriginal inhabitants of Australia, in course of time displaced by the present straight-haired Australian natives.

If the Tasmanian occupied his island when it formed continuous land with Australia, and arrived in it along with the marsupial mammals, his advent would go back to a time before land and water had assumed their present relations, thousands of years ago. If a great migration eastwards from Asia of the early Negritos did take place, they may at that period have reached Tasmania by way of the Australian continent. Though, as has already been stated, a woolly-haired race is not now represented in Australia, the tendency of the South Australians to show Tasmanian characters in the cranial vault is worthy of consideration in this particular, as an indication of the probable route of migration and of racial affinity.

When the level of land and water changed and the formation of Bass's Straits severed the two countries, Tasmania became isolated. Hence arose a condition, specially emphasised by Sir WM. FLOWER, in which their geographical position, outside the track of commerce and civilisation, precluded the Tasmanians from being crossed with and influenced by other races. Close inter-breeding was thus necessitated, which during the centuries and in a limited population would intensify, perpetuate, and give permanency to physical and other characters which might arise from time to time amongst them, and would accentuate differences between them and the parent stock from which they had sprung. Hence the Tasmanians would assume characters which would give them the aspect of a race distinct from the other races in more or less proximity to them. The evidence seems to be in favour of the descent of the Tasmanians from a primitive Negrito stock, which migrated across Australia, rather than by the route of the Melanesian Oceanic islands lying to the north and east of the Australian continent.

## SAGITTAL CONTOURS.

In my memoir on the Crania collected by the "Challenger" and in several subsequent publications I have figured vertical antero-posterior sections of skulls, made immediately on one side of the mesial plane, and I have stated the diameter of the lines radiating from the basion across the cranial cavity, to definite points on the surface of the skull, as well as certain other measurements.

In the third part of my memoir on Indian crania and in that on skulls from Borneo and other parts of Malaya I marked out a nasio-tentorial plane (*n.t.*) drawn from the nasion to the upper border of the groove for the lateral sinus, which divided the cranial cavity into a cerebral part above this plane, and a basal part for the lodgment of the cerebellum, pons, and medulla. Four of the radii from the basion intersected this plane, and divided the cerebral part of the cavity into regions which approximately represented the position

and relative size of the frontal, parietal and occipital lobes of the cerebrum. The point at which each radius intersected this plane is its tentorial point, and the segment of the radius which extends from this point to the vault is its tentorial segment. The tentorial segment of the basi-perpendicular radius, from the basion to a point on the cranial vault behind the bregma, drawn at right angles to the plane of the foramen magnum, has a general relation to the fissure of Rolando, in front of which is the frontal lobe: between the tentorio-perpendicular and tentorio-lambdal radii are the parietal and the upper end of the temporal lobe: behind the tentorio-lambdal radius is the occipital lobe.

In this memoir, instead of making sections of the skulls and reproducing the surface of section, I obtained tracings with Lissauer's apparatus of the cranial vault from the opisthion to the nasion, and by marking the position of the basion I have obtained the radial as well as the other measurements above referred to, and I have indicated by the dotted line the position of the foramen magnum (figs. 2, 3, 4, 5, 6, 7, p. 396).

Klaatsch, in a recent memoir,* has figured some Tasmanian skulls in the London and Paris museums traced with his diagraph. He has taken the glabella as a centre from which to draw lines to the bregma, lambda, occipital point and inion. From the glabella-inion line he has taken the height to the bregma, to the vault behind the bregma and to the lambda, as well as the chord of the arc from the glabella to the bregma. In relation to these radii he has measured the bregma angle and other angles. In addition to the Tasmanian skulls similar measurements of skulls of Australians, Europeans, and other nationalities have been recorded in his tables.

The glabella, owing to variations in its size and the degree of projection in individuals and in races, exercises an important influence on the character of the physiognomy, and is now almost universally employed as the point in front from which to measure the maximum length of the skull and the head, in the determination of the length-breadth or cephalic index. The range of variation in its projection, associated in a more or less degree with the development of the frontal sinuses, unfits it to be used for taking the point in front from which to estimate the length of the cerebral part of the cranial cavity.

As I desire to employ measurements which, as far as is consistent with the difference between a sagittal section and a sagittal contour, will enable a comparison to be made between the skulls now described and those studied in my previous memoirs, I have continued to employ the nasio-tentorial plane, and in Table III. I have stated the radial and other measurements previously adopted. Six of the male Tasmanian skulls were selected for this purpose, and they are designated by numbers corresponding to those specified in Table I. The contour of the vault of these skulls, Nos. 1, 2, 5, 6, 7, 10,† together with the lines of measurement, have been reproduced in Figs. 2, 3, 4, 5, 6, 7.

* *Zeitschrift für Ethnologie*, Heft 6, p. 875, 1903.

† No. 3 is that of a female, in No. 4 the skull-cap was loose, Nos. 8 and 9 were fragmentary; they are not figured.

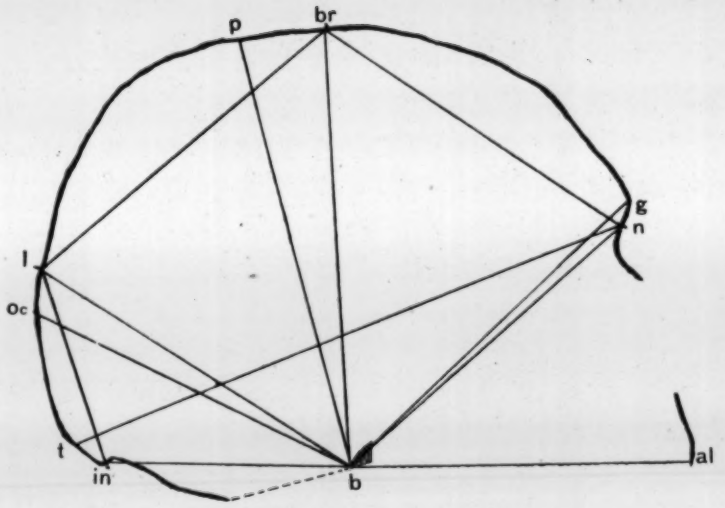


FIG. 2.—Tasmanian, xxx. No. 1.

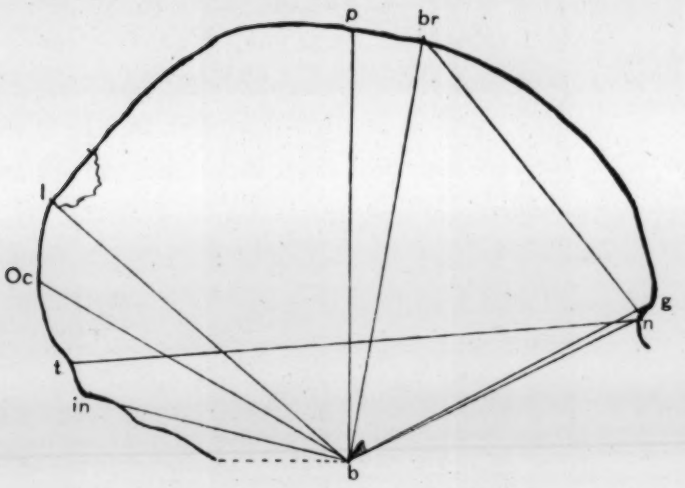


FIG. 3.—Tasmanian, xxx. No. 2.

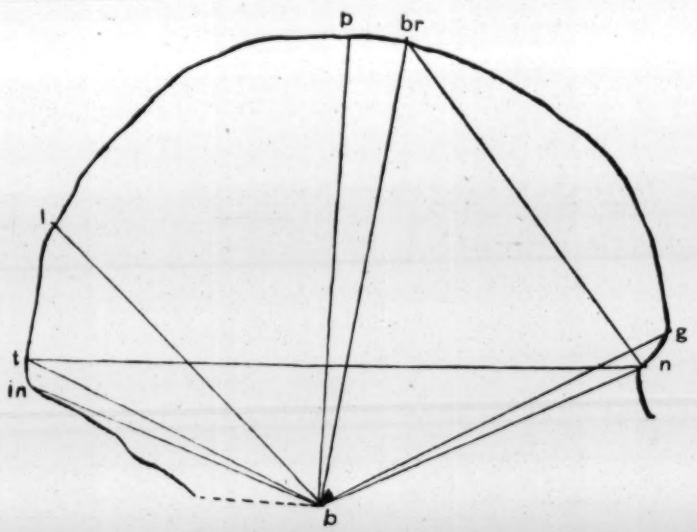


FIG. 4.—Tasmanian, xxx. No. 5.

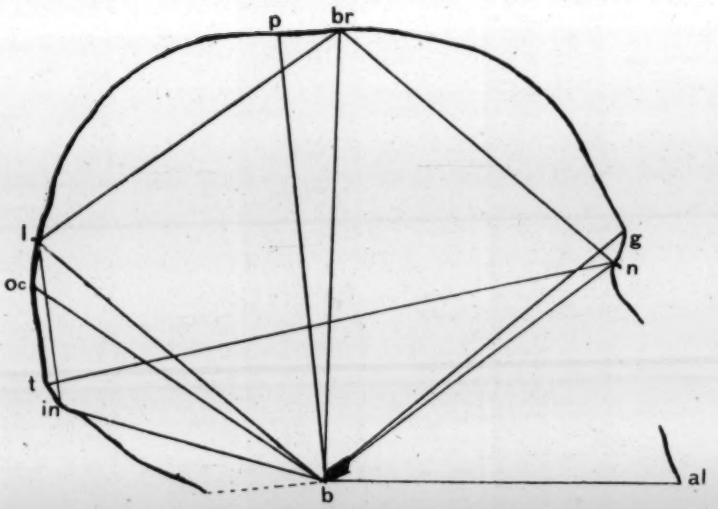


FIG. 5.—Tasmanian, xxx. No. 6.

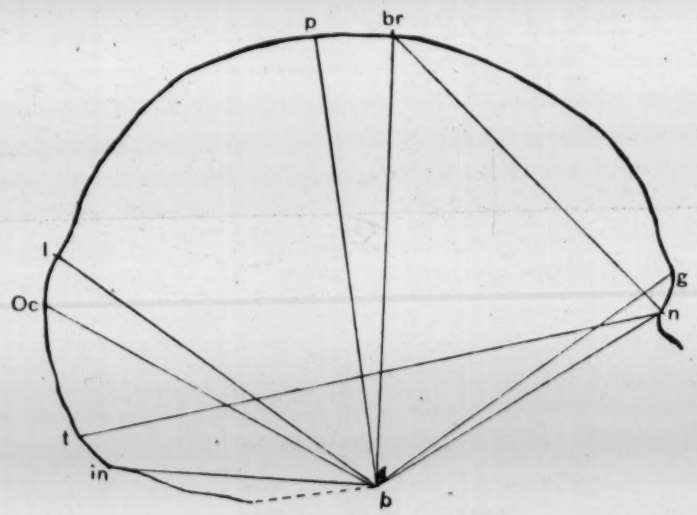


FIG. 6.—Tasmanian xxx. No. 7.

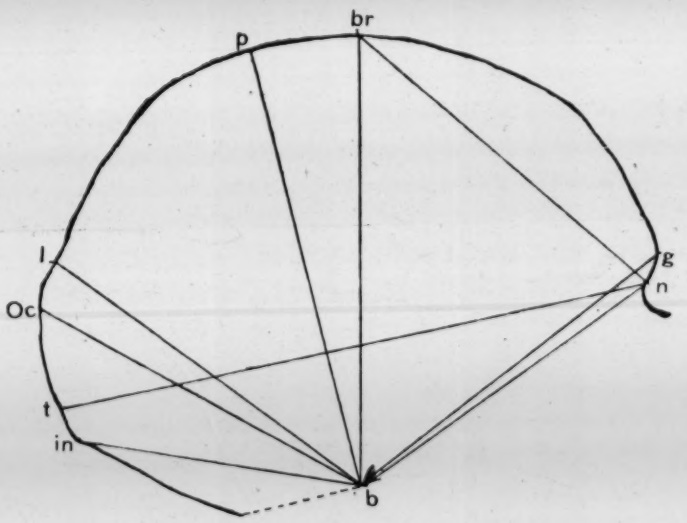


FIG. 7.—Tasmanian, xxx. No. 10.

## Table III.

*Tasmanian Sagittal Contours.*

| | Monro. No. 1. | No. 2. | No. 5. | No. 6. | No. 7. | Jameson. No. 10. |
|---|---|---|---|---|---|---|
| Basi-inial radius, *b.i.* | 73 mm. | 81 mm. | 88 mm. | 81 mm. | 80 mm. | 80 mm. |
| „ -occipital radius, *b.oc.* | 100 „ | 106 „ | 91 „ | 104 „ | 113 „ | 102 „ |
| „ -lambdal, *b.l.* „ | 107 „ | 117 „ | 107 „ | 110 „ | 117 „ | 105 „ |
| „ -perpendicular radius, *b.p.* | 133 „ | 130 „ | 131 „ | 134 „ | 137 „ | 126 „ |
| „ -bregmatic, *b.br.* „ | 132 „ | 129 „ | 133 „ | 134 „ | 136 „ | 125 „ |
| „ -glabellar, *b.g.* „ | 118 „ | 104 „ | 109 „ | 117 „ | 110 „ | 105 „ |
| „ -nasial, *b.n.* „ | 107 „ | 101 „ | 96 „ | 107 „ | 100 „ | 96 „ |
| „ -alveolar, *b.al.* „ | 105 „ | 98 „ | 94 „ | 108 „ | 101 „ | 101 „ |
| Nasio-tentorial plane, *n.t.* | 176 „ | 172 „ | 172 „ | 173 „ | 178 „ | 166 „ |
| Tentorio-bregmatic segment, | 92 „ | 92 „ | 92 „ | 87 „ | 101 „ | 87 „ |
| „ -perpendicular „ | 94 „ | 94 „ | 92 „ | 87 „ | 103 „ | 88 „ |
| „ -lambdal „ | 62 „ | 68 „ | 54 „ | 53 „ | 73 „ | 54 „ |
| „ -occipital „ | 47 „ | 45 „ | ... | 41 „ | 62 „ | 44 „ |
| From perpendicular radius to point on arch of frontal above glabella, | 99 „ | 89 „ | 92 „ | 93 „ | 95 „ | 97 „ |
| From perpendicular radius to occipital point, | 80 „ | 95 „ | 88 „ | 80 „ | 92 „ | 76 „ |
| Collective height of four diameters from tentorial plane, | 295 „ | 299 „ | 238 „ | 268 „ | 339 „ | 273 „ |
| Total length and collective height, | 474 „ | 483 „ | 418 „ | 441 „ | 526 „ | 446 „ |
| Parieto-squamous breadth, | 130 „ | 139 „ | 134 „ | 125 „ | 141 „ | 127 „ |
| Collective height, length, breadth, | 604 „ | 622 „ | 552 „ | 566 „ | 667 „ | 573 „ |

A comparison of these tracings and of the measurements in Table III. may be made with the figures 1–10 in plates vi., vii. of my "Challenger" Report, 1884, in which Australians, an Admiralty Islander, other Oceanic crania, etc. are represented, and with table xviii. (p. 120) in which the radial measurements are given; also with my memoirs on the Craniology of the People of Scotland, pl. v. figs. 21–26, and table xvii., p. 609; the Craniology of the People of India, part ii., p. 128, and part iii., pp. 303, 308; the Craniology of the People of Borneo and other parts of Malaya, pl. xlv. figs. 27–29, and table iv., p. 806.

Owing to the contour tracings being on the outer surface of the vault, the length of the cerebral cavity cannot be stated precisely, as in two previous memoirs, when sagittal sections were reproduced, but the distance from the perpendicular radius to the frontal and the occipital points affords an indication of its long diameter; neither can the height of the cavity estimated by the collective tentorio-bregmatic, -perpendicular, -lambdal, and -occipital diameters be precisely given; but, subject to the deduction of five or six millimetres, representing the thickness of the skull, from each diameter, the figures given in Table III. express approximately the length and height of the cerebral cavity. The greatest breadth of the cavity, although not capable of being measured in an antero-posterior contour tracing, may, subject to a deduction for the thickness of the skull, be estimated from the parieto-squamous diameter. By adding this diameter to those of the four diameters taken from the tentorial plane to the points specified on the surface

of the vault, together with the long diameter from the perpendicular radius to the frontal and occipital points, a numerical statement can be obtained for each skull of the relative proportion of the cranial cavity occupied by the cerebrum proper, and a comparison of its magnitude in the several skulls can be made. The series of six male skulls ranged from 552 mm. in No. 5 to 667 mm. in No. 7.

If the length of the radii from the basion to the inion, to the occipital point, lambda, perpendicular point, and bregma, were conjoined with the parieto-squamous breadth and with the long diameter from the occipital to the frontal points, a comparative estimate of the internal capacity of the entire cranium in each skull could be formed. It is unnecessary, however, to compute the cranial capacity in this way, as I have stated in Table I., p. 367, the exact amount, as determined with shot, by the method which I am in the habit of pursuing. It will be seen that No. 7, with the largest cranial capacity, 1430 c.c., had also the highest measurement, 667 mm., for the cerebral portion of the cavity, whilst No. 5, with an internal capacity 1140 c.c., and No. 10 with 1100 c.c., had space for the cerebrum indicated by 552 and 573 mm. respectively.

In recent memoirs by Professors Cunningham, Schwalbe, and Klaatsch, the curvature of the arc of the frontal bone in the Neanderthal and other prehistoric skulls has been compared with the same region in the crania of savage and civilised men. The method employed has been to draw a chord from the bregma either to the nasion or to the glabella, and to erect a perpendicular line from this chord to the most prominent part of the frontal arc, the degree of curvature of which influences the length of the line. Some time ago I adopted the method of Cunningham, and in Part III. of my contributions to Indian Craniology, and in my account of crania from Borneo and other parts of Malaya, I measured the chord from the nasion to the bregma, and took the length of a perpendicular line from it to the most projecting part of the frontal arc. In this memoir I have continued this practice, and have taken, in addition, the chord of the arc of the parietal bone from bregma to lambda, and that of the occipital from lambda to inion.* In each case I have erected a perpendicular to the most prominent part of the arch of each bone. The results of the measurements of six male Tasmanians are given in Table IV.

Table IV.

| | Monro. No. 1. | No. 2. | No. 5. | No. 6. | No. 7. | Jameson. No. 10. |
|---|---|---|---|---|---|---|
| Nasio-bregmatic chord of frontal, *br.n.*, | 109 mm. | 105 mm. | 111 mm. | 107 mm. | 115 mm. | 105 mm. |
| Perpendicular therefrom to outer surface of bone, . . . . | 23 ,, | 20 ,, | 27 ,, | 25 ,, | 25 ,, | 24 ,, |
| Bregma-lambdal chord of parietal, *br.l.*, | 112 ,, | 121 ,, | 112 ,, | 110 ,, | 121 ,, | 106 ,, |
| Perpendicular therefrom to outer surface of bone, . . . . | 26 ,, | 26 ,, | 22 ,, | 25 ,, | 25 ,, | 21 ,, |
| Lambda-inial chord of occipital, *l.in.*, | 62 ,, | 60 ,, | 46 ,, | 51 ,, | 66 ,, | 51 ,, |
| Perpendicular therefrom to outer surface of bone, . . . . . | 10 ,, | 9 ,, | 3 ,, | 4 ,, | 10 ,, | 7 ,, |

* In my "*Challenger*" *Report* 1884 the chords of the frontal, parietal and occipital arcs of several skulls are given in table xix. The mean of three Australian skulls was: frontal chord 112·6, parietal 118·3, occipital 92·3.

The length of the nasio-bregmatic chord varied from 105 to 115 mm., with the mean 108·5 mm., a measure which closely corresponded with the mean 108 of the chord of the arc of the Indian crania given in Table VI. of Part III. (*supra cit.*). The length of the perpendicular erected from this chord in the Tasmanians ranged from 20 to 27 mm.; but the mean 24 mm. of the six skulls was less than the mean, 26·7 mm., in eight Indian skulls, and materially below the length, 27 mm. and 28 mm. respectively, of the two Scottish skulls recorded in the same table.

The bregma-lambdal chord of the parietal bone ranged from 106 mm., to 121 mm., with the mean 113·6 mm. The perpendicular therefrom to the highest part of the bone ranged from 21 to 26 mm., with the mean 24·1 mm., which closely corresponded with the mean of the projection of the frontal bone, and showed that these bones had almost similar curvatures.

The lambda-inial chord of the occipital bone ranged from 46 to 66 mm., with the mean 56 mm. The perpendicular therefrom ranged from 3 to 10 mm., with the mean 7·1 mm. These figures confirmed the statements made in the description of the occipital region of these skulls (p. 370), of the feeble projection of the occipital squama in the males, and of the short diameter from lambda to inion. In connection with the occipital region in the Tasmanian skulls, I recall a paper which I published in 1864, when the Neanderthal skull began to be the subject of controversy. Professor HUXLEY had directed attention to the characters of this skull, and had shown that not only the frontal but the occipital region possessed remarkable features, for the inial protuberance formed in it the posterior pole of the skull so that the squama sloped upwards and forwards and the occipital lobe of the brain would have been flattened and diminished. I investigated at that time both the frontal and occipital regions in the Australian and Tasmanian crania then in the Anatomical Museum of the University, and recognised a form of the occipital squama similar to that of the Neanderthal skull in some of the specimens. I also pointed out that it would be possible to arrange a series of modern British skulls in which variations from a well-marked occipital bulging to a form closely approaching that of the Neanderthal skull could be seen.

In Table I. the total longitudinal circumference of the skulls is given, computed from the total longitudinal arc, the length of the foramen magnum and the basi-nasal diameter. Two of these factors, viz. the length of the foramen magnum and the basi-nasal diameter, constitute the "base-line" of CLELAND, and in Table V. the proportion of the base-line to the total longitudinal arc, and to the total longitudinal circumference of the skull, is shown.

TABLE V.

| | No. 1. | No. 2. | No. 5. | No. 6. | No. 7. | No. 10. |
|---|---|---|---|---|---|---|
| Base line of male Tasmanian skulls, . | 143 mm. | 138 mm. | 120 mm. | 140 mm. | 135 mm. | 131 mm. |
| Total longitudinal arc, . . . | 358 „ | 356 „ | 357 „ | 359 „ | 382 „ | 342 „ |
| Longitudinal circumference, . . | 501 „ | 494 „ | 487 „ | 499 „ | 517 „ | 473 „ |
| Base-line to longitudinal arc, . . | 2·5 „ | 2·5 „ | 2·9 „ | 2·5 „ | 2·8 „ | 2·6 „ |
| „ „ „ circumference, | 3·5 „ | 3·5 „ | 4·0 „ | 3·5 „ | 3·8 „ | 3·6 „ |

The mean length of the base-line was 134·5 mm., that of the total longitudinal arc 359 mm., and that of the total longitudinal circumference 495 mm. The range in the proportion of base-line to the longitudinal arc varied in the Tasmanian skulls from 2·5 to 2·9, with the mean 2·63; whilst the proportion to the longitudinal circumference ranged from 3·5 to 4, with the mean 3·65. The skull No. 5 was that which possessed the greatest proportion of base-line both to the longitudinal arc and to the circumference.

I have elsewhere shown that the mean base-line in seventeen Scottish skulls was to the arc as 1 to 2·8, and in twenty male Australians as 1 to 2·7. The larger the proportion of arc to base-line the greater is the curvature of the vault of the skull for the lodgment of the cerebrum.

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## EXPLANATION OF PLATES I.–III.

The process blocks are reproduced from photographs of the objects prepared by Mr Ernest J. Henderson of the Anatomical Museum.

### Plate I.

Fig. 1. Face of a Tasmanian from a mask in wax in the Anatomical Museum.

Figs. 2, 3, 4. Fronto-parietal views of three male Tasmanian skulls to show the characters of the vault, page 369. Fig. 2, the skull No. 2 in Table I.; fig. 3, the skull No. 5; fig. 4, the skull in the collection formed by Professor Jameson, numbered 10 in that Table.

### Plate II.

Fig. 5. Norma verticalis of the skull from the Monro collection, No. 1 in the Table. This is the only touched photograph.

Fig 6. Norma lateralis of the same skull.

„ 7. Norma facialis of the same skull.

„ 8. Norma lateralis of the skull No. 10 from the Jameson collection.

### Plate III.

Fig. 9. Norma verticalis of skull, No. 10 from the Jameson collection.

„ 10. Norma lateralis of the same skull.

„ 11. Norma facialis of female skull, No. 3 in Table I.

„ 12. Norma lateralis of the same skull.

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## EXPLANATION OF FIGURES IN TEXT.

Fig. 1, page 369. Tracings of transverse arcs of No. 10: *f*, 35 mm. in front of bregma; *ap*, 1 cm. behind bregma; *mp*, about the middle of the parietal eminences.

Figs. 2 to 7, page 396. Mesial sagittal tracings of six male Tasmanian skulls.

| | | | |
|---|---|---|---|
| *b.* | Basion. | *b.oc.* | Basi-occipital radius. |
| *b.al.* | Basi-alveolar radius. | *b.in.* | „ -inial „ |
| *b.n.* | „ nasal „ | *n.t.* | nasio-tentorial plane. |
| *b.g.* | „ glabellar „ | *n.br.* | „ -bregmatic chord. |
| *b.br.* | „ bregmatic „ | *br.l.* | bregma-lambdal „ |
| *b.p.* | „ perpendicular „ | *l.in.* | -lambda-inial „ |
| *b.l.* | „ lambdal „ | | |

The dotted line is the plane of the foramen magnum. The serrated line in fig. 3 is the outline of a Wormian bone.

SIR WILLIAM TURNER on "Craniology of the Aborigines of Tasmania."—PLATE I.

FIG. 1.—Face of Tasmanian.

FIG. 2.—Tasmanian ♂.

FIG. 3.—Tasmanian ♂.

FIG. 4.—Tasmanian ♂.

SIR WILLIAM TURNER on "Craniology of the Aborigines of Tasmania."—PLATE II.

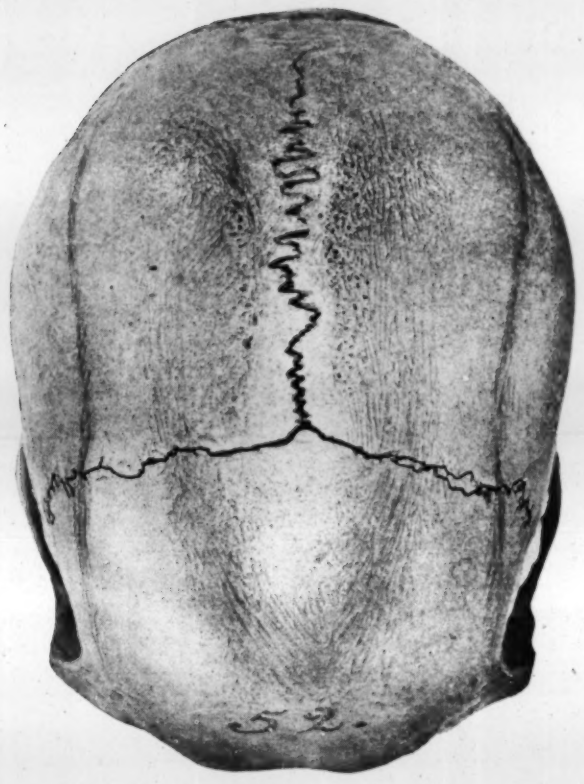

FIG. 5.—Tasmanian ♂.

FIG. 6.—Tasmanian ♂.

FIG. 7.—Tasmanian ♂.

FIG. 8.—Tasmanian ♂.

SIR WILLIAM TURNER on "Craniology of the Aborigines of Tasmania."—PLATE III.

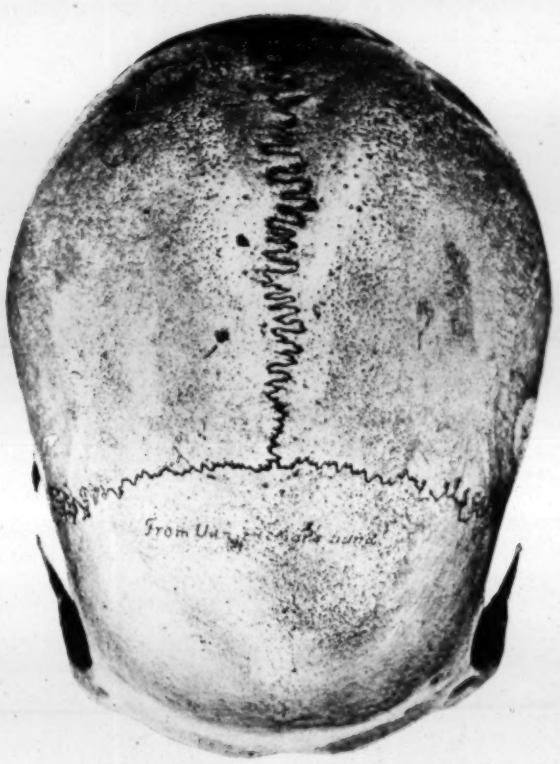

FIG. 9.—Tasmanian ♂.

FIG. 10.—Tasmanian ♂.

FIG. 11.—Tasmanian ♀.

FIG. 12.—Tasmanian ♀.

# XVIII.—Les Holothuries de l'Expédition Antarctique Nationale Écossaise.

Par **Clément Vaney**, Maître de conférences de Zoologie à la Faculté des Sciences de Lyon. *Présentées par M.* W. S. Bruce, LL.D. (Avec cinq planches.)

(MS. received May 20, 1908. Read June 15, 1908. Issued separately October 15, 1908.)

La *Scotia* a rapporté de son expédition au pôle sud une très importante collection d'Holothuries ; nous remercions bien vivement M. W. S. Bruce de l'honneur qu'il nous a fait en nous en confiant l'étude.

Cette collection ne renferme pas moins de trente-quatre espèces, dont vingt et une, c'est à dire près des deux tiers, sont nouvelles. Cette proportion aurait été probablement plus grande, mais par suite de l'action de quelques agents conservateurs employés (formaldéhyde et acide acétique glacial) certains échantillons sont indéterminables : leurs corpuscules calcaires ayant été complètement dissous par les liquides acides. Pour la même raison nous avons décrit quelques nouvelles espèces sans pouvoir fournir dans la diagnose les caractères de leurs spicules. Mais la majeure partie des exemplaires et surtout ceux de grandes profondeurs sont en bon état et très bien préparés.

Cette collection de l'expédition écossaise est actuellement une des plus importantes au point de vue des Holothuries de grandes profondeurs des mers antarctiques. Elle renferme deux espèces de Synallactidés et onze espèces d'Elasipodes, comprenant quatre Elpiidés et sept Psychropotidés, parmi lesquelles dix sont nouvelles.

La *Scotia* a recueilli un grand nombre de Cucumariidés, dont dix espèces nouvelles proviennent en majeure partie des Orcades du Sud. Nous avons déjà eu l'occasion * de signaler deux nouvelles Thyone de ces mêmes îles. Ces faits prouvent la grande variété de faune de cette région.

Certaines de ces nouvelles espèces de Cucumariidés : le *Psolidium Coatsi* et les *Cucumaria psolidiformis* et *C conspicua*, constituent de curieux termes de transition entre les genres *Cucumaria* et *Psolidium*. Les deux *Cucumaria*, qui appartiennent à l'ancien genre *Semperia*, possèdent de gros pédicelles disposés suivant des rangées radiales et de nombreux petits pédicelles disséminés sur tout le corps ; leur trivium présente une ébauche de sole ventrale souvent mal délimitée. Ce dernier caractère les rapproche des *Psolidium convergens* (Hérouard), *Ps. panamense* Ludwig et *Ps. ornatum* (E. Perrier), dont la sole n'est pas limitée latéralement. Une autre forme de *Cucumaria*, la *C. armata*, présente de grandes affinités avec le genre *Colochirus*.

L'expédition antarctique nationale écossaise a retrouvé les *Cucumaria antarctica*, *C. grandis* et *C. lateralis*, rapportées pour la première fois par l'expédition du

* "Deux nouvelles Thyone des Orcades du Sud (*Thyone Scotiæ* et *Thyone turricatus*)," *Bull. Mus. Hist. Nat. Paris*, 1906, p. 400.

Dr CHARCOT ; ces nouveaux exemplaires nous ont permis de compléter nos descriptions antérieures.

A son retour, la *Scotia* a recueilli au cap de Bonne Espérance une nouvelle espèce de *Thyone*, la *T. articulata*, et les *Cucumaria discolor* et *C. insolens* de THÉEL.

Nous indiquons dans le tableau suivant la répartition des différentes espèces d'Holothuries rapportées par la *Scotia*.*

| | Lat. S. | Long. W. | Profondeur. |
|---|---|---|---|
| SYNALLACTIDÉS— | | | Brasses. |
| Pseudostichopus villosus, Théel | 69° 33′ | 15° 19′ | 2620 |
| | 67 33 | 36 35 | 2500 |
| *Synallactes Robertsoni*, nov. sp. | 66 40 | 40 35 | 2425 |
| ELPIIDÉS— | | | |
| Scotoplanes globosa, Théel | 39 48 | 2 33 E. | 2645 |
| *Peniagone Mossmani*, nov. sp. | 69 33 | 15 19 | 2620 |
| ,, *Piriei*, nov. sp. | 66 40 | 40 35 | 2425 |
| ,, *Wiltoni*, nov. sp. | 69 33 | 15 19 | 2620 |
| PSYCHROPOTIDÉS— | | | |
| *Benthodytes spuma*, nov. sp. | 69 33 | 15 19 | 2620 |
| ,, *Browni*, nov. sp. | 48 06 | 10 05 | 1742 |
| ,, *recta*, nov. sp. | 67 39 | 36 10 | 2500 |
| *Euphronides Scotiæ*, nov. sp. | 62 10 | 41 20 | 1775 |
| *Psychropotes longicauda*, Théel, var. *antarctica*, nov. var. | 71 22 | 16 34 | 1410 |
| *Psychropotes laticauda*, nov. sp. | 67 39 | 36 10 | 2500 |
| | 39 48 | 2 33 E. | 2645 |
| ,, *Brucei*, nov. sp. | 67 33 | 36 35 | 2500 |
| CUCUMARIIDÉS— | | | |
| Psolus antarcticus (Philippi) | Port Stanley, Iles Falkland | | 5 à 10 |
| Psolidium convergens (Hérouard) | ,, ,, | | ... |
| *Psolidium* (*Cucumaria*) *Coatsi*, nov. sp. | Baie de la Scotia | | 9 à 10 |
| *Thyone articulata*, nov. sp. | Baie de Saldanha, Afrique du Sud | | 9 à 10 |
| Cucumaria antarctica, Vaney | Baie de la Scotia, Orcades du Sud | | 9 à 10 |
| ,, crocea (Lesson) | Port Stanley, Iles Falkland | | 3 à 4 |
| | 51° 7′ S. | 9° 31′ W. | 2103 |
| ,, discolor, Théel | Baie de Saldanha, Afrique du Sud | | rivage |
| ,, grandis, Vaney | Baie de la Scotia, Orcades du Sud | | 9 à 10 |
| ,, lateralis, Vaney | ,, ,, | | 9 à 10 |
| ,, lævigata, Verrill | Banc de Burdwood | | 56 |
| ,, leonina, Semper | Port Stanley, Iles Falkland | | ... |
| ,, insolens, Théel | Baie de Saldanha, Afrique du Sud | | ... |
| *Cucumaria analis*, nov. sp. | Baie Jessie, Orcades du Sud | | ... |
| ,, *armata*, nov. sp. | Port William, Iles Falkland | | 6 |
| ,, *aspera*, nov. sp. | Baie de la Scotia, Orcades du Sud | | 10 |
| ,, *conspicua*, nov. sp. | ,, ,, | | 9 à 10 |
| ,, *croceoïda*, nov. sp. | Banc de Burdwood | | 56 |
| ,, *perfida*, nov. sp. | Baie de la Scotia, Orcades du Sud | | 9 à 10 |
| ,, *periprocta*, nov. sp. | ,, ,, | | ... |
| ,, *psolidiformis*, nov. sp. | ,, ,, | | 10 |
| ,, *secunda*, nov. sp. | ,, ,, | | 9 à 10 |

* Les espèces nouvelles sont en italiques.

# ASPIDOCHIROTES.

## SYNALLACTIDÉS.

### Pseudostichopus, Théel.

*Pseudostichopus villosus*, Théel.

Station 420, 21 Mars 1904 ; lat. S. 69° 33′, long. W. 15° 19′ ; profondeur 2620 brasses. Un exemplaire.

Station 291, 7 Mars 1903 ; lat. S. 67° 33′, long. W. 36° 35′ ; profondeur 2500 brasses. Un exemplaire.

Cette espèce parait avoir une répartition géographique assez grande : le *Challenger* l'a recueillie en une dizaine de stations comprises entre 62° 26′ et 38° 6′ de latitude sud et 2° 56′ et 35° 22′ de latitude nord, à des profondeurs variant de 1375 à 2900 brasses. Théel signale simplement que les exemplaires de l'hémisphère nord diffèrent peut-être un peu de ceux de l'hémisphère sud par les corpuscules calcaires et la forme des pédicelles. Nos exemplaires sont franchement antarctiques, puisqu'ils ont été recueillis entre 67° et 69° 33′ de latitude sud ; par suite, il est intéressant d'en donner une description assez complète pour permettre ultérieurement les comparaisons avec les échantillons septentrionaux.

Leur corps est ovale, un peu aplati dorso-ventralement ; leur longueur est de 100 millimètres et leur plus grande largeur, située vers le milieu du corps, atteint 50 millimètres. La bouche est ventrale et est à 10 millimètres du bord antérieur. L'anus est ventral mais presque terminal ; il est encadré par les deux lobes latéraux, caractéristiques du genre *Pseudostichopus*, de forme hémisphérique et ayant 5 à 6 millimètres de diamètre.

Les téguments sont souples et minces ; leur coloration est marron, les côtés et les extrémités du corps sont de teinte plus foncée que les faces dorsale et ventrale. Les pédicelles ont leur extrémité brunâtre, ils sont très abondants et disséminés irrégulièrement sur les parties latérales du corps. Sur la face ventrale, ces appendices forment une double série de pointillés ; ils s'étendent, de part et d'autre de la ligne médiane, sur les deux quarts moyens du corps et laissent complètement nu le radius médian ventral. Les appendices de la face dorsale sont difficiles à observer, leur répartition parait irrégulière.

Les corpuscules calcaires ont été complètement dissous par le liquide conservateur.

L'intérieur des téguments est blanchâtre ; les bandes musculaires longitudinales sont marron clair, elles ont toutes la même importance, et atteignent 5 à 6 millimètres de largeur. L'anneau calcaire est composé de dix pièces : les radiales sont massives, elles ont 5 millimètres de longueur et les interradiales, en forme de chevron, ont 3 à 4 millimètres. La vésicule de Poli unique est transparente et mesure 10 à 12 millimètres de

longueur. Le tube digestif a 10–12 millimètres de diamètre et présente un estomac différencié de 30 millimètres de longueur.

Vers le milieu du corps sont disposées deux grappes de follicules ovariens jaunâtres, embrassant plus ou moins le tube digestif ; l'oviducte est long et mince.

Les organes arborescents sont brunâtres avec des ramifications brun foncé ; ils affectent la forme d'un **Y** dont la branche commune a 15 millimètres de longueur et les branches latérales 35 et 45 millimètres.

### Synallactes, Ludwig.

*Synallactes Robertsoni*, nov. sp. (Pl. III. fig. 34, 35 et 36.)

Station 295, 10 Mars 1903 ; lat. S. 66° 40′, long. W. 40° 35′. Un exemplaire.

L'état de conservation de cet exemplaire laisse beaucoup à désirer : il est en partie pelé et éviscéré ; cependant malgré ces défectuosités nous pouvons en fournir une diagnose assez complète.

L'échantillon est de couleur blanc jaunâtre avec des pédicelles de teinte plus foncée. Son corps est aplati dorso-ventralement ; sa longueur est de 75 millimètres et sa largeur atteint 15 à 18 millimètres. L'extrémité postérieure est légèrement atténuée et arrondie. La bouche et l'anus sont franchement terminaux.

La face ventrale est légèrement convexe ; elle présente suivant ses radius des pédicelles brunâtres. Sur les radius latéro-ventraux, nous trouvons une seule rangée composée de trente à quarante pédicelles, très rapprochés les uns des autres vers le région anale mais assez écartés dans la région antérieure. On constate en quelques points l'indication d'une double rangée. Suivant le radius médian, on trouve sur le quart postérieur une dizaine de pédicelles, irrégulièrement disposés sur deux rangées ; les deux quarts médians paraissent dépourvus de pédicelles, mais sur le quart antérieur une dizaine de ces appendices sont disposés en une double rangée.

La face dorsale est en majeure partie pelée, mais dans les régions intactes on distingue des papilles peu élevées, à base élargie, réparties uniformément sur toute la face dorsale et au nombre d'une huitaine dans le sens de la largeur.

La couronne tentaculaire est plus ou moins recouverte par un repli péribuccal ; elle comprend seize tentacules se terminant chacun par un disque muni sur son pourtour de six à huit digitations repliées sur elles-mêmes.

Les corpuscules calcaires des téguments sont constitués par des tourelles à base tétraradiée (fig. 34 et 35), dont chacune des branches a son extrémité distale aplatie, élargie et percée d'une grande ouverture centrale accompagnée d'une ou deux perforations plus petites. Au centre de la base s'élève une tige simple terminée en pointe et offrant quelques piquants disséminés sur toute sa longueur.

La paroi des pédicelles renferme des bâtonnets (fig. 36) à extrémités bifides portant latéralement quelques piquants.

Les muscles longitudinaux sont jaunâtres ; ils ont deux millimètres de largeur. L'organisation interne semble indiquer l'existence d'une bordure latérale.

La vésicule de Poli unique a 6 millimètres de longueur et possède des parois transparentes. Les organes génitaux sont composés d'un faisceau d'une vingtaine de tubes simples, jaunâtres, qui atteignent 10 à 15 millimètres de longueur.

Dans le même flacon nous trouvons un tube digestif muni à l'une de ses extrémités de deux organes arborescents, presque égaux, mesurant 20 millimètres de longueur et offrant chacun deux séries longitudinales de cœcums latéraux. Il est très probable que ces viscères sont ceux de cette Synallactidé.

*Rapports et Différences.*—L'ensemble de l'organisation et la forme des corpuscules calcaires nous amènent à considérer cet échantillon comme appartenant au genre *Synallactes*.

Les Synallactidés recueillies dans la région antarctique comprennent actuellement les *Pseudostichopus mollis* Théel et *Ps. villosus* Théel, les *Mesothuria bifurcata* Hérouard, *M. magellani* (Ludwig) et *M. Thomsoni* (Théel), les *Synallactes Challengeri* (Théel) et *S. Carthagei* Vaney, le *Bathyplotes Moseleyi* (Théel).

Le *Synallactes Robertsoni* et le *Synallactes Challengeri* (Théel) offrent entre eux quelques points communs par suite de la répartition des pédicelles et de la forme des corpuscules ; mais dans notre espèce les rangées de pédicelles médians ventraux ne sont pas continues et la tige centrale des corpuscules est élancée et présente une série de piquants sur toute sa longueur.

## ELPIDIIDÉS.

### Scotoplanes, Théel.

*Scotoplanes globosa*, Théel. (Pl. III. fig. 25, 26, 27 et 28.)

(?) Synonyme : *Sc. Murrayi*, Théel.

Station 468, 29 Avril 1904 ; lat. S. 39° 48′, long. E. 2° 33′ ; profondeur 2645 brasses. Quatre exemplaires.

Ces exemplaires sont très bien étalés et conservés, quoiqu'une grande partie des corpuscules calcaires aient été dissous par le liquide conservateur (formol à $2\frac{1}{2}\%$). Les téguments sont minces et transparents, les tentacules et les appendices sont légèrement rosés. La longueur du corps est comprise entre 70 et 120 millimètres et la largeur oscille entre 30 et 55 millimètres ; ces échantillons sont donc de plus petite taille que ceux rapportés par le *Challenger*. Comme dans le type décrit par Théel on trouve, sur la face dorsale, trois paires de papilles dont les deux premières sont très développées et dissymétriques et la troisième, très postérieure, est rudimentaire.

Ces échantillons ne présentent que six pédicelles sur chaque radius latéro-ventral : le deuxième, le troisième et quelquefois le quatrième sont les plus grands, les cinquième et sixième sont les plus petits. Ce nombre invariable de six paires de pédicelles latéro-ventraux sépare la plupart de nos exemplaires de l'espèce type, qui présente toujours sept paires de ces appendices. En nous basant sur cette différence nous pensions tout d'abord que les exemplaires de la *Scotia* représentaient les types d'une nouvelle variété de la *Scotoplanes globosa* Théel, à laquelle nous aurions donné le nom de *sexpedata*. La création de cette nouvelle variété pouvait aussi être basée sur ce que les corpuscules calcaires sont de plus petite taille que ceux décrits par Théel. Les téguments renferment des corpuscules en C (fig. 27) de 0·08 millimètres, des corpuscules mamelonnés (fig. 28) et des bâtonnets très épineux dont les plus grands (fig. 25) atteignent 0·40 millimètres de longueur, tandis que les petits (fig. 26), généralement moins épineux, n'ont que 0·15 millimètres. Théel avait observé dans sa *Sc. globosa* des corpuscules en C de 0·16 millimètres et des bâtonnets épineux de 0·92 millimètres, c'est à dire des corpuscules qui sont deux fois plus grands que ceux que nous trouvons dans nos échantillons. Les tentacules de nos exemplaires offrent aussi quelques particularités : leur disque terminal a une dizaine de prolongements périphériques et comme dans l'espèce type deux sont plus importants, mais leur surface externe présente une série de papilles.

Tout cet ensemble de caractères différentiels nous autorisaient à créer la variété *sexpedata* de la *Sc. globosa*, mais un exemplaire, qui nous a été communiqué récemment, a modifié notre opinion. Cet échantillon est dissymétrique ; il présente sur la face ventrale sept pédicelles à droite et six seulement à gauche ; il sert d'intermédiaire entre les types du *Challenger* et la plupart des exemplaires de la *Scotia*. Il est donc inutile d'établir une variété spéciale pour les exemplaires à six paires de pédicelles. Nous en déduisons simplement que la *Sc. globosa* peut subir des réductions dans le nombre de ses pédicelles : tous les échantillons du *Challenger* ont sept paires de ces appendices, presque tous ceux de la *Scotia* n'en ont que six paires. Il est très probable que la *Sc. Murrayi*, établie par Théel sur un unique exemplaire, correspond à une variété de la *Sc. globosa* qui n'aurait que cinq paires de pédicelles, car ses corpuscules calcaires sont presque semblables à ceux de la *Sc. globosa*.

Les nombreux exemplaires de la *Sc. globosa* rapportés par le *Challenger* avaient été recueillis : les uns à 1950 brasses de profondeur par 53° 55′ de lat. S. et 108° 35′ de long. E., les autres à 2160 brasses par 33° 31′ de lat. S. et 74° 43′ de long. W. Les échantillons de la *Scotia* ont été recueillis à une profondeur plus considérable et à une latitude intermédiaire. Le type de la *Sc. Murrayi* provenait de 60° 52′ lat. S. et de 1260 brasses de profondeur.

PENIAGONE, Théel.

*Peniagone Mossmani*, nov. sp. (Pl. I. fig. 10 et 11 ; Pl. II. fig. 19 ; Pl. III. fig. 32 et 33.)

Station 420, 21 Mars 1904 ; lat. S. 69° 33′, long. W. 15° 19′; profondeur 2620 brasses.. Un exemplaire.

L'exemplaire est en mauvais état de conservation : il est pelé et recouvert de vase. Son corps, ovale et allongé, mesure 70 millimètres de longueur et 25 millimètres de plus grande largeur vers le tiers antérieur. La face dorsale est légèrement convexe ; la face ventrale (fig. 10) est aplatie et présente, en avant, un disque buccal saillant de 8 à 9 millimètres de diamètre. Au centre de ce disque se trouve l'ouverture buccale, qui est probablement entourée d'une dizaine de tentacules. Une rangée de pédicelles, bien visible sur le côté gauche, est disposée de chaque côté de la sole ventrale. La première paire de ces appendices est à 20 millimètres du bord antérieur, la deuxième à 15 millimètres de la première ; quant aux autres, au nombre de cinq à six, ils sont plus petits et très rapprochés les uns des autres ; ils semblent former par leur ensemble une bordure périanale. Sur la face dorsale (fig. 11) le disque buccal est surmonté d'un capuchon ou voile étalé en éventail et s'insérant à 10 millimètres du disque suivant toute la largeur du corps. Ce capuchon présente (fig. 19) trois paires de pointes latérales ; sa plus grande hauteur est de 8 millimètres. Les téguments dorsaux étant en partie enlevés, nous n'avons pu distinguer s'il y avait d'autres appendices.

Les corpuscules calcaires ont été altérés par la formaldéhyde, leurs contours sont devenus crênelés. Ces corpuscules sont des croix à quatre branches (fig. 32 et 33) plus ou moins incurvées ; vers le centre de la croix et à la base de deux branches opposées, se trouvent deux courts mamelons coniques. La plupart de ces corpuscules cruciformes paraissent lisses, pourtant quelques-uns offrent quelques denticulations à l'extrémité des bras. Il existe deux vésicules de Poli inégales ayant l'une 7 et l'autre 4 millimètres de longueur. Les organes génitaux sont formés de deux glandes en grappe de couleur brunâtre.

*Rapports et Différences.*—La *Peniagone Mossmani* se rapproche de la *Kolga furcata* Hérouard (*Periamma furcatum* d'après R. PERRIER) provenant des Açores. Ces deux espèces ont un voile formé de trois paires de papilles, mais chez l'espèce d'HÉROUARD elles sont plus nettement séparées les unes des autres que dans notre espèce et le voile ne s'étend pas sur toute la largeur du corps. Les corpuscules calcaires sont différents dans les deux espèces.

La seule forme d'Elpiidé antarctique qui puisse être comparée avec notre *Peniagone Mossmani* est la *Peniagone Challengeri* Théel recueillie à 50° 1′ de latitude sud et à 1800 brasses de profondeur ; mais cette espèce est plus allongée que notre *Peniagone* et son voile est formé par la coalescence d'une paire de papilles dorsales ; d'ailleurs ses corpuscules calcaires sont épineux et bien différents de ceux de notre espèce.

*Peniagone Piriei*, nov. sp. (Pl. I. fig. 4 et 5.)

Station 295, 10 Mars 1903 ; lat. S. 66° 40′, long. W. 40° 35′ ; profondeur 2425 brasses. Un exemplaire.

Cet exemplaire est bien épanoui, mais malheureusement, par suite de l'action de la formaldéhyde, tous les corpuscules calcaires ont été dissous.

Le corps est ovale et mesure 100 millimètres de longueur ; sa plus grande largeur se trouve au niveau du tiers postérieur et atteint 40 à 45 millimètres. La face ventrale (fig. 4) est aplatie et présente en avant la bouche entourée de dix tentacules placés sur un cercle de 15 millimètres de diamètre. L'anus est nettement terminal. A 40 millimètres en arrière de l'ouverture buccale commencent les rangées latéro-ventrales de pédicelles ; celles-ci sont disposées en un fer à cheval dont chaque branche se compose d'une seule série de huit pédicelles. La taille de ces appendices va en décroissant d'avant en arrière : les antérieurs ont 5 millimètres de longueur, les pédicelles de la dernière paire sont de petite taille et réunis l'un à l'autre par une sorte de crête transversale. La distance entre les appendices latéro-ventraux d'une même rangée va aussi en diminuant d'arrière en avant : les antérieurs sont à 10 millimètres les uns des autres, les postérieurs à 5 millimètres seulement.

La face dorsale (fig. 5) est fortement convexe et la plus grande hauteur du corps atteint 40 millimètres. Sur le côté dorsal et à 15 millimètres du bord antérieur émerge un gros appendice conique dirigé d'arrière en avant et ayant 20 millimètres de longueur ; il est légèrement aplati dans le sens frontal ; sa base a 15 millimètres de largeur et 10 millimètres d'épaisseur. Ce gros appendice dorsal se termine en une pointe bifide et à une petite distance de son sommet se trouve de chaque côté une petite papille latérale : il semble être formé par la fusion de quatre papilles dorsales. A 20 millimètres en arrière de ce gros appendice se trouve, sur la face dorsale, une paire de petites papilles de 3 à 4 millimètres de longueur et distantes l'une de l'autre de 10 millimètres.

Les tentacules, au nombre de dix, sont composés chacun d'un pédoncule de 3 millimètres de longueur et de 4 millimètres de diamètre terminé par un disque plus ou moins convexe de 5 millimètres de diamètre et dont la surface externe est recouverte de nombreuses petites papilles.

La vésicule de Poli, unique, est brunâtre et a 20 millimètres de longueur. La glande génitale est située à droite ; elle est en grappe compacte et a une longueur de 25 millimètres.

*Rapports et Différences.*—La *Peniagone Piriei* peut être rapprochée de la *Peniagone vitrea* Théel, recueillie par le *Challenger* par 42° 43′ de latitude sud et à 1450 brasses de profondeur, et de la *P. intermedia* Ludwig provenant de l'océan Pacifique. Toutes ces espèces ont un voile dorsal avec deux lobes médians saillants, mais notre *Peniagone* a la bouche moins infléchie vers la face ventrale que chez les deux autres formes. D'ailleurs

la forme subantarctique, *P. vitrea*, s'en distingue par la présence de deux paires de papilles dorsales et d'une collerette périanale.

Comme autre *Peniagone* subantarctique pouvant être comparée à la *P. Piriei*, nous avons la *P. purpurea* Théel, recueillie par le *Challenger* par 46° 16′ et 53° 55′ de latitude sud, à une profondeur de 1950 brasses. Cette forme de THÉEL est de petite taille et présente un voile dorsal composé par deux appendices très grêles et séparés l'un de l'autre sur une grande partie de leur longueur.

Nous devons aussi comparer la *P. Piriei* avec la *Scotoplanes robusta* THÉEL, recueillie par le *Challenger* par 53° 55′ de latitude sud et à 1950 brasses de profondeur. Cette *Scotoplanes* est une Elpiidé de grande taille, mesurant 133 millimètres de longueur et dont les pédicelles latéro-ventraux, au nombre de onze paires, ont une disposition assez semblable à celle observée dans notre espèce ; mais son voile dorsal est bien différent de celui de la *Peniagone Piriei* : il est composé par deux paires de papilles de taille presque identiques et ayant 10 millimètres de longueur.

*Peniagone Wiltoni*, nov. sp. (Pl. I. fig. 6 et 7 ; Pl. III. fig. 29, 30 et 31.)

Station 420, 21 Mars 1904 ; lat. S. 69° 33′, long. W. 15° 19′ ; profondeur 2620 brasses. Un exemplaire.

Cet échantillon est en partie pelé ; les téguments blanc grisâtre se détachent en certains points et sont recouverts de vase sur presque toute leur surface.

Le corps (fig. 6) est obovale, il mesure 85 millimètres de long et sa plus grande largeur, qui se trouve vers le quart antérieur, atteint 40 millimètres. La face ventrale est aplatie et la face dorsale légèrement bombée. L'extrémité postérieure du corps est arrondie; l'extrémité antérieure présente une région buccale de 10 millimètres de diamètre, assez bien séparée du reste du corps et portant sur sa face ventrale l'ouverture buccale.

Les pédicelles ne semblent pas avoir été conservés dans leur intégrité : sur la face ventrale, nous en trouvons un plus grand nombre à droite qu'à gauche. A droite, ces appendices, au nombre de quatre, sont disposés en une rangée le long du radius latéro-ventral ; le premier est à 20 millimètres de la région buccale, le deuxième à 12 millimètres du premier, le troisième et le quatrième à 20 millimètres des appendices les précédant immédiatement. Chacun de ces appendices a 8 à 10 millimètres de longueur et 4 à 5 millimètres de diamètre. Sur le côté gauche, nous ne trouvons plus que deux pédicelles correspondant aux appendices moyens du côté droit. L'anus, qui est terminal mais légèrement dorsal, parait bordé par une petite collerette.

Nous observons une semblable dissymétrie sur la face dorsale (fig. 7). On trouve tout d'abord en avant et sur la région buccale une sorte de petit capuchon triangulaire de 5 millimètres de hauteur en mauvais état de conservation. A 10 millimètres en arrière se présente une paire de gros appendices coniques, très rapprochés l'un de l'autre et mesurant 20 millimètres de longueur et 7 à 8 millimètres de diamètre à la base.

A 10 millimètres en arrière de cette paire d'appendices dorsaux et un peu sur le côté gauche, on distingue une unique papille de 10 millimètres de longueur et de 3 millimètres de diamètre.

La couronne tentaculaire parait se composer d'une dizaine de tentacules qui ont tous disparus.

Les téguments renferment des bâtonnets épineux sur toute leur surface (fig. 31) et des corpuscules étoilés à quatre branches. Tantôt ceux-ci ont des bras simples recouverts de nombreux piquants (fig. 30), tantôt les branches sont surmontées vers leur base d'un petit mamelon épineux (fig. 29).

Les organes génitaux constituent deux glandes en grappe à parois transparentes.

*Rapports et Différences.*—Il est difficile de préciser la place générique de cette nouvelle Elpiidé ; mais par suite de la présence d'un voile très réduit et de corpuscules tétraradiés nous pouvons la considérer comme appartenant au genre *Peniagone.*

Nous devons comparer cette *P. Wiltoni* à la *Kolga nana* Théel. Le *Challenger* avait recueilli cette dernière espèce, soit dans les régions arctiques soit dans les régions antarctiques, mais il est très probable que la forme antarctique est simplement *analogue* à celle des régions arctiques ; d'ailleurs Théel indique qu'elle n'était représentée que par un seul individu incomplet recueilli à 60° 52′ de latitude sud et à 1260 brasses de profondeur. Sa longueur est de 28 millimètres et ses pédicelles latéro-ventraux sont au nombre de neuf paires : ils sont donc plus nombreux que dans notre espèce. La face dorsale de la *K. nana* présente quatre papilles disposées en une rangée transversale, les médianes étant les plus larges. Les corpuscules calcaires sont aussi différents dans les deux espèces.

## PSYCHROPOTIDÉS.

### Benthodytes, Théel.

*Benthodytes spuma*, nov. sp. (Pl. I. fig. 1 ; Pl. II. fig. 20.)

Station 420, 21 Mars 1904 ; lat. S. 69° 33′, long. W. 15° 19′ ; profondeur 2620 brasses. Un exemplaire.

Cet unique échantillon a un aspect gélatineux ; il nous a rappelé à ce point de vue le *Pelopatides gelatinosus* (Walsh). La coloration est grisâtre sur la face dorsale et d'un noir violacé sur la face ventrale. Le corps est légèrement aplati sur la face ventrale, mais le radius médian est assez saillant, surtout dans sa région moyenne ; l'aplatissement est bien marqué dans les régions antérieure et postérieure du corps. La face dorsale est un peu convexe ; les téguments ont un aspect plus gélatineux dans cette région que dans les autres parties de l'animal. Cet exemplaire mesure 155 millimètres de longueur et 45 millimètres de plus grande largeur.

L'anus est terminal ; la bouche est nettement ventrale, et est située à 20 millimètres du bord antérieur. Elle est entourée de seize tentacules noir violacé munis de courts pédoncules ; le disque terminal de ces tentacules a 4 millimètres de diamètre, il est convexe et présente de nombreuses petites papilles périphériques.

La région antérieure du corps (fig. 1) offre une collerette péribuccale de 30 millimètres de largeur, composée d'une quarantaine de petites papilles en forme de festons à bords arrondis. Entre la collerette péribuccale et le cercle tentaculaire, les téguments de la face ventrale sont recouverts de nombreuses petites verrucosités ou plissements. A la collerette buccale, fait suite, de chaque côté du corps, une rangée longitudinale de petits appendices noir violacé, nettement séparés les uns des autres et ne constituant pas par leur ensemble de bordure latérale. On retrouve de semblables petites papilles noir violacé disséminées sans ordre sur toute la face dorsale (fig. 20). Dans la région postérieure, on distingue une collerette périanale, s'arrêtant au niveau de l'anus et formée d'un certain nombre de festons plus ou moins turgescents.

A 15 millimètres en arrière de la bouche commencent les rangées de pédicelles du radius médian ventral qui s'arrêtent à 10 millimètres en avant de l'anus. Ces appendices sont au nombre de quatre-vingt-cinq disposés en deux rangées plus ou moins alternantes et ils sont très rapprochés les uns des autres.

Malgré toutes nos recherches nous n'avons pu trouver de corpuscules calcaires soit dans les parois du corps soit dans les tentacules et les organes génitaux. Il est très probable qu'ils ont été dissous par les liquides conservateurs.

La vésicule de Poli unique a 20 millimètres de longueur.

Les organes génitaux sont constitués par deux glandes de 40 millimètres de longueur présentant chacune un canal central grisâtre portant de distance en distance des faisceaux de cæcums plus ou moins arborescents.

L'intestin est de coloration grisâtre, le rectum est noir violacé et il présente un petit cæcum sur la moitié de sa longueur.

*Rapports et Différences.*—Nous ne pouvons guère rapprocher la *Benthodytes spuma* que de la *B. abyssicola* Théel ; mais celle-ci s'en distingue facilement parce qu'elle a quinze tentacules, des processus dorsaux de petite dimension mais répartis au nombre d'une dizaine par radius dorsal ; elle possède aussi une bordure latérale composée de pédicelles plus développés que ceux du radius médian ventral.

On a déjà signalé dans les régions antarctiques deux espèces de *Benthodytes* : la *B sanguinolenta* Théel et la *B. sordida* Théel. La *B. sanguinolenta* a dix-huit tentacules, une bordure latérale formée de nombreux appendices et elle est pourvue de minuscules papilles dorsales. Le *B. sordida* a quinze tentacules, une bordure latérale formée de nombreux appendices et des appendices dorsaux de différentes tailles. Les deux espèces antarctiques de *Benthodytes* déjà décrites sont donc bien distinctes de notre *B. spuma.*

*Benthodytes Browni*, nov. sp. (Pl. I. fig. 2 et 3.)

Station 451, 13 Avril 1904 ; lat. S. 48° 06′, long. W. 10° 05′ ; profondeur 1742 brasses. Un exemplaire.

Le corps de cet exemplaire est plus ou moins cylindrique, avec les régions antérieure et postérieure arrondies. La face ventrale est légèrement aplatie, surtout dans sa région médiane, tandis que la face dorsale est fortement bombée. La longueur de cet individu est de 200 millimètres, sa largeur est de 50 millimètres et sa hauteur 35 millimètres. Les téguments sont plissés et fortement pigmentés, leur coloration est d'un noir uniforme.

La bouche (fig. 3) est ventrale et située à 10 millimètres du bord antérieur, l'anus est terminal. La bouche est entourée de quatorze tentacules, tous de même grandeur. Chaque tentacule se compose d'un pédoncule d'une dizaine de millimètres de long, surmonté d'un disque convexe de 10 millimètres de diamètre, à surface terminale papilleuse et présentant sur son pourtour quelques digitations assez fortement rétractées.

Les radius dorsaux (fig. 2) sont très saillants et ils sont nettement séparés l'un de l'autre par une région déprimée, surtout dans la moitié postérieure du corps. Sur presque toute la longueur de chaque radius sont disposés, en une seule rangée, une vingtaine d'appendices coniques, à peu près tous identiques et ayant une base d'une dizaine de millimètres de diamètre. Dans la région antérieure ces papilles sont de taille plus petite et, sur le radius droit, nous en trouvons deux au même niveau. Une rangée de seize pédicelles s'étend sur toute la longueur de chaque radius latéro-ventral (fig. 3) ; chacun de ces pédicelles présente une base élargie conique, dont le diamètre atteint 12 millimètres ; cette partie est plus ou moins plissée et elle est surmontée d'un petit mamelon cylindrique et rétractile de 5 millimètres de longueur et de 2 millimètres de diamètre. Les deux rangées ambulacraires latéro-ventrales sont parallèles et ne sont reliées par aucune bordure postanale.

Le radius médian ventral est marqué par deux bandes longitudinales, en dépression sur le reste de la sole, et sillonnées par de nombreux traits transversaux. A un premier examen externe nous ne trouvions aucun appendice sur ce radius, mais l'étude interne décèle dans le quart postérieur une huitaine de pédicelles disposés sur deux rangées plus ou moins alternantes.

Les téguments sont épais ; leur coloration est noirâtre à l'extérieur et violacée à l'intérieur. Ils ne renferment aucune trace de corpuscule, mais cela est très probablement dû à l'action du formol.

Les organes génitaux sont constitués de deux houppes de très nombreux tubes grêles de 20 à 35 millimètres de longueur et de couleur rouge violacé. L'unique vésicule de Poli mesure 30 millimètres de longueur ; elle est de couleur gris violacé.

*Rapports et Différences.*—La *Benthodytes Browni* est nettement caractérisée par la

forme de ses gros appendices latéro-ventraux et dorsaux et par la localisation des pédicelles médio-ventraux sur le quart postérieur du corps.

Dans le groupe des *Benthodytes* pourvues de quatorze tentacules, la *B. curiosa* doit être comparée à la *B. Janthina* Marenzeller trouvée dans l'Atlantique nord ; mais celle-ci se distingue de notre espèce par des différences de taille entre les diverses papilles dorsales et par le grand nombre de pédicelles de la région marginale et du radius médian ventral. La *B. curiosa* s'éloigne aussi de la *B. mamillifera* Théel, espèce qui peut n'avoir aussi que quatorze tentacules, mais dont le pourtour est bordé par de nombreux pédicelles de petite taille et dont le radius dorsal offre cinquante petits processus coniques disposés suivant deux rangées plus ou moins alternantes.

*Benthodytes recta*, nov. sp. (Pl. II. fig. 23 ; Pl. III. fig. 37 et 38.)

Station 291, 7 Mars 1903 ; lat. S. 67° 33′, long. W. 30° 35′ ; profondeur 2500 brasses. Trois exemplaires.

Parmi ces trois exemplaires un est complètement pelé, les deux autres, quoique en assez mauvais état, peuvent pourtant servir à caractériser cette nouvelle espèce. Les dimensions respectives de ces deux échantillons sont : pour l'un, 150 millimètres de longueur et 30 millimètres de largeur, et, pour l'autre, 110 millimètres de longueur et 20 millimètres de largeur. Leur corps est plus ou moins aplati, la face ventrale quoique légèrement convexe est beaucoup moins bombée que la face dorsale.

La coloration générale est rouge violacé, mais la face ventrale est de teinte plus foncée que la face dorsale. La bouche est franchement ventrale et plus ou moins saillante ; elle est entourée par seize tentacules grisâtres, dont le disque terminal est convexe et à surface externe pustuleuse. L'anus est plutôt ventral que terminal.

On distingue une collerette péribuccale qui se continue de chaque côté du corps par une bordure peu saillante formée d'une cinquantaine de papilles ou festons. En arrière, ces bordures latérales se réunissent l'une à l'autre par une collerette périanale formée de deux lobes se séparant au niveau de l'anus.

Le radius médian ventral possède un grand nombre de pédicelles disposés en deux rangées longitudinales, alternant irrégulièrement l'une avec l'autre et s'étendant sur toute la longueur du radius.

Chaque radius dorsal (fig. 23) peut posséder au plus quatre papilles ; les trois antérieures sont de plus petites dimensions que la postérieure ; elles atteignent, chez le petit exemplaire, 2 à 4 millimètres de longueur, tandis que la papille postérieure a 10 millimètres. Le petit échantillon présente la première papille à 14 millimètres du bord antérieur, la seconde papille à 8 millimètres de la première, la troisième à 23 millimètres de la deuxième et la dernière à 40 millimètres de la précédente. Chez le grand exemplaire ces distances respectives sont 30 millimètres, 20 millimètres, 25 (?) millimètres et 45 millimètres.

Les téguments sont minces et renferment des corpuscules calcaires en forme de croix (fig. 37) à quatre branches inégales et incurvées, présentant sur leur longueur quelques piquants massifs. Dans les tentacules sont des bâtonnets arqués (fig. 38), quelquefois à extrémités bifides ; leur taille varie beaucoup.

*Rapports et Différences.*—La *Benthodytes recta* est une espèce de *Benthodytes* à seize tentacules, qui se sépare nettement des espèces déjà décrites. Parmi les espèces antarctiques, elle a quelques affinités avec la *B. sordida* Théel, mais cette dernière a quinze tentacules, trois paires de grands processus dorsaux entre lesquels sont des papilles plus petites, et une bordure latérale bien différente de celle de notre espèce.

## Euphronides, Théel.

*Euphronides Scotiæ*, nov. sp. (Pl. I. fig. 8 et 9 ; Pl. III, fig. 39 et 40.)

Station 313, 18 Mars 1903 ; lat. S. 62° 10′, long. W. 41° 20′ ; profondeur 1775 brasses. Un exemplaire.

Cet exemplaire a une longueur de 140 millimètres et une largeur de 45 millimètres environ. La face dorsale est légèrement bombée, sa coloration est blanc grisâtre avec quelques reflets rosés. La face ventrale est aplatie ; sa coloration générale est brunâtre, mais son pourtour et sa portion médiane sont verdâtres. La bouche est ventrale et se trouve située à 10 millimètres du bord antérieur ; l'anus est aussi compris dans la sole ventrale et est aussi à 10 millimètres du bord postérieur.

La sole ventrale (fig. 9) est entourée, sur tout son pourtour, par une bordure festonnée. La partie circumorale comprend une vingtaine de festons de faible épaisseur et très peu échancrés ; les portions latérales sont composées, de chaque côté, par une quarantaine de festons faisant peu de saillie et infléchis du côté ventral ; mais à 30 millimètres environ, en avant de l'anus, la bordure s'étale à nouveau pour constituer la collerette périanale ; cette dernière est formée par une trentaine de festons peu découpés.

Le radius médian ventral fait légèrement saillie sur une largeur de 10 millimètres environ et, suivant toute sa longueur, se trouvent répartis soixante-cinq pédicelles disposés en deux rangées plus ou moins irrégulièrement alternantes. De chaque côté de ce radius, la sole ventrale présente toute une série de paires de stries transversales.

Le cercle tentaculaire est entouré par un repli brunâtre ; il comprend seize tentacules brunâtres. Chaque tentacule se termine par un disque offrant à sa surface un grand nombre de petites verrucosités.

La face dorsale (fig. 8) est fortement plissée et présente à 105 millimètres du bord antérieur un gros appendice impair de 20 millimètres de largeur à sa base et de 15 millimètres de hauteur ; son extrémité libre est arrondie. En avant de ce gros appendice se trouve, vers le milieu du corps, une paire de petites papilles de 2 millimètres de longueur, plus ou moins cachées par les replis des téguments. Ces petites papilles sont

à 15 millimètres l'une de l'autre. L'ouverture génitale est à 20 millimètres du bord antérieur.

Les téguments sont minces et flexibles ; ceux de la face dorsale sont légèrement rugueux, ils renferment des corpuscules tri- et tétraradiés (fig. 39 et 40) dont les branches, souvent un peu incurvées, offrent quelques piquants ; ils sont de différentes tailles et présentent tous un piquant central.

L'organisation interne montre bien que le gros appendice dorsal provient de la soudure de deux papilles. Des fragments calcaires, en mauvais état de conservation placés autour de la bouche, semblent être les restes d'un anneau calcaire. La vésicule de Poli unique est de couleur rose violacé et mesure 30 millimètres de longueur.

Les ovaires sont constitués par deux petites grappes s'étendant sur 20 millimètres de longueur.

*Rapports et Différences.*—Notre *Euphronides Scotiæ* doit être comparée d'une part avec les *E. Tanneri* Ludwig et *E. depressa* Théel, espèces à un seul grand appendice dorsal, mais qui s'en distinguent par la présence de dix-huit tentacules, et d'autre part, avec les *E. verrucosa* Ludwig et *E. bifurcata* Koehler et Vaney, qui possèdent comme elle seize tentacules, mais dont les téguments sont fortement verruqueux.

L'*Euphronides Scotiæ* est plus antarctique que l'*E. depressa* proprement dite * recueillie par le *Challenger* sur les côtes de Patagonie.

### Psychropotes, Théel.

*Psychropotes longicauda*, Théel, var. *antarctica*, nov. var.

Station 417, 18 Mars 1904; lat. S. 71° 22′, long. W. 16° 34′ ; profondeur 1410 brasses. Un exemplaire.

Cet exemplaire diffère de l'espèce type de Théel par quelques caractères secondaires, cependant nous n'avons pas cru devoir l'en séparer complètement par suite du manque de corpuscules calcaires ; ceux-ci ont été probablement dissous par la formaldéhyde.

Cet échantillon a 280 millimètres de longueur et seulement 50 millimètres de largeur ; il est donc plus allongé que le type de Théel, dont la largeur est environ le tiers de la longueur. Le corps est plutôt cylindrique, sa largeur reste constante suivant toute la longueur ; les extrémités antérieure et postérieure sont légèrement arrondies. La face ventrale est aplatie, la face dorsale est convexe, mais elle n'offre pas en arrière la surélévation indiquée par Théel dans son *Ps. longicauda*. La coloration est gris violacé, les bords marginaux sont brun foncé.

La région caudale s'insère à 4–5 millimètres en avant de l'extrémité postérieure; elle est conique et mesure 100 millimètres de longueur et 25 millimètres de largeur à sa base d'insertion. Son extrémité libre se termine par deux digitations presque égales :

* Voir R. Perrier, *Holothuries : Exp. Sc. du "Travailleur" et du "Talisman,"* 1902, p. 434.

l'une de 8 millimètres de longueur, l'autre de 6 millimètres seulement. La bouche et l'anus sont tous deux dans la sole ventrale ; la bouche est à 15 millimètres du bord antérieur et l'anus à 5 millimètres du bord postérieur. Le radius médian ventral renferme une cinquantaine de pédicelles brunâtres, rétractés et répartis en deux rangées alternantes. Sur le pourtour de la sole ventrale, on trouve, en avant, une collerette péribuccale de faible épaisseur, formée par quinze petits festons, qui se continue de chaque côté par une simple rangée d'une quarantaine de pédicelles assez distants les uns des autres. En arrière, ces deux rangées se réunissent l'une à l'autre par une sorte de collerette périanale à festons mal définis.

La face dorsale présente, comme le type de *Ps. longicauda*, quatre paires de petites papilles situées successivement à 50, 60, 80 et 100 millimètres du bord antérieur.

Les téguments sont minces mais malheureusement complètement débarrassés de leurs corpuscules calcaires.

Les glandes génitales sont composées de deux glandes en grappe de 60 millimètres de longueur, formée chacune d'une série de vésicules de couleur gris violacé. La vésicule de Poli unique est blanc grisâtre et mesure 70 millimètres de longueur.

Cet exemplaire appartient au *Ps. longicauda* Théel, car il possède, comme cette espèce, dix-huit tentacules, quatre paires de papilles dorsales, mais ici la région caudale se termine par deux digitations presque égales, le corps est plus élancé et il ne présente ni bordure latérale ni surélévation postérieure.

Les exemplaires rapportés par le *Challenger* avaient été recueillis en trois stations différentes : l'une située à 62° 26′ lat. S. et 95° 44′ long. E. et à 1975 brasses de profondeur, l'autre à 53° 55′ lat. S. et 108° 35′ long. E., à 1950 brasses de profondeur, et enfin la troisième à 34° 7′ lat. S. et 73° 56′ long. W., à 2225 brasses de profondeur.

Théel avait déjà séparé, parmi les exemplaires de la deuxième station, deux variétés : la variété *monstrosa* et la variété *fusco-purpurea*.

Quoique la taille de notre échantillon et la longueur de sa région caudale atteignent presque celles du type de la variété *montrosa*, il en diffère par la forme générale du corps et l'absence de bordure latérale. Notre exemplaire est beaucoup plus antarctique que cette variété et par ses divers caractères il parait être le type d'une nouvelle variété à laquelle nous donnons le nom d'*antarctica*.

*Psychropotes laticauda*, nov. sp. (Pl. II. fig. 14 et 24.)

Station 290, 6 Mars 1904 ; lat. S. 67° 39′, long. W. 36° 10′ ; profondeur 2500 brasses. Un exemplaire.

Station 468, 29 Avril 1904 ; lat. S. 39° 48′, long. E. 2° 33′ ; profondeur 2645–2900 brasses. Un exemplaire.

Les deux exemplaires, quoique provenant de deux stations assez distantes l'une de l'autre, appartiennent sans aucun doute à la même espèce. L'un des échantillons est

rempli de vase et semble avoir conservé sa forme primitive ; c'est sur celui-ci que nous établirons les caractères de la nouvelle espèce. Comme le *Ps. longicauda* Théel, notre nouveau *Psychropotes* est surélevé en arrière, où sa hauteur atteint 45 millimètres, tandis qu'il offre en avant un aplatissement très marqué. La largeur du corps est sensiblement la même sur toute la longueur et est comprise entre 50 et 55 millimètres ; la longueur atteint de 185 à 190 millimètres. La coloration générale des téguments est violet rougeâtre ; la teinte est foncée sur la face ventrale et grisâtre sur la face dorsale ; les pédicelles ont leurs extrémités brunâtres.

La face ventrale (fig. 14) est aplatie et forme une sole aux extrémités de laquelle sont la bouche et l'anus ; la bouche est à 30 millimètres du bord antérieur et l'anus à 10 millimètres du bord postérieur ; chacune de ces ouvertures est entourée d'une collerette. La collerette péribuccale se compose d'une vingtaine de pédicelles très élargis à la base et terminés par une digitation de 4 à 5 millimètres de long ; elle s'infléchit assez fortement en arrière de la bouche. La collerette périanale comprend quatorze festons très larges à contours presque arrondis ; seules les papilles postérieures offrent un petit mamelon. Les extrémités correspondantes de ces collerettes sont réunies l'une à l'autre par une rangée d'une dizaine de pédicelles latéro-ventraux de grosse taille et bien séparés.

Le radius médian ventral présente une trentaine de pédicelles répartis irrégulièrement sur deux rangées alternantes. Dans la moitié postérieure les pédicelles sont très rapprochés ; il en est de même vers le voisinage immédiat de la bouche ; mais dans le reste de ce radius médian, ils sont très largement espacés.

Sur la face dorsale se trouvent deux paires de petites papilles ; la première est à 80 millimètres du bord antérieur, l'autre à 100 millimètres de cette extrémité. L'appendice caudal est placé tout à fait à l'arrière, il est aplati dorso-ventralement et est terminé par une pointe arrondie semblant provenir de la soudure intime de deux papilles égales. La queue a une longueur de 60 millimètres et une largeur à la base de 35 millimètres.

Le cercle tentaculaire est composé de dix-huit tentacules brunâtres. Chacun de ceux-ci présente un pédoncule violet de 10 millimètres de long, terminé par un disque violet brunâtre de 8 millimètres de diamètre dont la partie distale est convexe, à surface rugueuse et porte, sur son pourtour, une vingtaine de papilles plus ou moins rétractées.

Les téguments sont plus minces sur la face dorsale que sur la face ventrale ; ils renferment des corpuscules étoilés (fig. 24) à quatre ou six branches plus ou moins incurvées, sur lesquelles sont disposées de distance en distance quelques piquants. Au centre du corpuscule s'élève toujours un piquant plus développé que les autres et à pointe mousse.

Les muscles longitudinaux sont marron brunâtre, l'intestin est grisâtre. La vésicule de Poli unique est grisâtre et mesure 40 millimètres de longueur.

Les organes génitaux sont constitués par deux grappes d'une vingtaine de vésicules blanc jaunâtre, placées à l'extrémité d'un canal de 35 millimètres de longueur.

*Rapports et Différences.*—Le *Psychropotes laticauda* se rapproche du *Ps. longicauda* Théel ; il s'en distingue par le petit nombre et la taille des pédicelles latéro-ventraux, par la répartition hétérogène des pédicelles médio-ventraux et par la forme et la terminaison de la région caudale.

Cette nouvelle espèce rappelle aussi le *Ps. raripes* Ludwig, car tout deux ont des pédicelles latéro-ventraux bien séparés les uns des autres ; mais dans le *Ps. raripes*, les corpuscules calcaires sont beaucoup plus épineux que dans notre *Ps. laticauda*, d'ailleurs les pédicelles du radius impair sont répartis différemment dans ces deux espèces, de plus notre *Ps. laticauda* a des appendices dorsaux alors que le *Ps. raripes* en est dépourvu.

La répartition inégale des pédicelles médio-ventraux, le petit nombre d'appendices dorsaux et l'absence de toute bordure latérale reliant les pédicelles latéro-ventraux sépare le *Ps. laticauda* du *Ps. buglossa* Perrier ; les corpuscules calcaires sont d'ailleurs différents dans ces deux espèces.

*Psychropotes Brucei*, nov. sp. (Pl. I. fig. 13 ; Pl. II. fig. 21 et 22 ; Pl. III. fig. 41 et 42.)

Station 291, 7 Mars 1903 ; lat. S. 67° 33′, long. W. 36° 35′ ; profondeur 2500 brasses. Un exemplaire.

Le corps est allongé et de coloration gris jaunâtre ; sa longueur est de 170 millimètres et sa largeur de 50 millimètres environ. La face ventrale aplatie (fig. 21) est de couleur plus foncée que la face dorsale, celle-ci est légèrement bombée. La bouche et l'anus sont nettement ventraux. En avant, l'exemplaire présente une collerette péribuccale de 40 à 44 millimètres de diamètre formée de vingt-six papilles assez saillantes. Autour de l'anus, on trouve une série de huit paires de petites papilles jaunâtres disposées sur un cercle de 30 millimètres de diamètre. Sur le côté, le corps présente une bordure latérale qui déborde d'un centimètre environ vers la région antérieure et de quelques millimètres seulement vers la région postérieure. Sous cette bordure s'étend, de chaque côté du corps, de la collerette péribuccale à la collerette périanale, une rangée d'une huitaine de pédicelles bien séparés entre eux, dont les trois premiers sont assez distants les uns des autres. Le radius médian ventral est fortement rétracté et plissé ; malgré nos recherches faites en étalant cette région ou en examinant la face interne, nous n'avons pu distinguer aucun appendice.

La bouche est située à 22 millimètres du bord antérieur ; elle est entourée de dix-huit tentacules brun rougeâtre disposés un peu irrégulièrement. Chaque tentacule se termine par un disque de 7 millimètres de diamètre, à surface externe convexe, papilleuse et bordée de festons périphériques plus ou moins rétractés ; leur pédoncule est court et blanc jaunâtre.

Vu de côté (fig. 22), le corps se termine, dans sa région postérieure, par une sorte de talon surmonté d'une région caudale très saillante, aplatie latéralement, terminée en

pointe, cintrée en avant et offrant une double inflexion telle que la pointe est reportée presque au-dessus du talon. La hauteur de cette région caudale est de 60 millimètres et sa longueur à la base atteint 35 millimètres. Sur la face dorsale (fig. 13) se trouvent l'ouverture génitale, située à 40 millimètres du bord antérieur et, plus en arrière, deux paires de petites papilles. La première paire est à 5 millimètres de l'ouverture génitale et présente un écartement de 10 millimètres ; la deuxième paire est à 15 millimètres plus en arrière et offre un écartement de 20 millimètres.

Les téguments renferment des corpuscules cruciformes (fig. 41 et 42) dont les branches sont fortement épineuses. Au centre du corpuscule s'élève toujours un piquant.

Le tube digestif est marron clair, mais le rectum est noirâtre. Les muscles longitudinaux des radius sont de couleur marron.

Les organes génitaux sont composés de deux faisceaux d'une dizaine d'ampoules. Chaque faisceau aboutit à un canal de 20 millimètres de longueur. Les plus grosses ampoules sont ovales et ont 10 millimètres de plus grand diamètre.

*Rapports et Différences.*—Si réellement le radius médian ventral du *Psychropotes Brucei* est dépourvu de pédicelles, cette espèce se rapprocherait du *Ps. Grimaldii* Hérouard de l'Atlantique, qui possède aussi dix-huit tentacules. Mais notre nouveau *Psychropotes* se sépare très nettement de la forme décrite par HÉROUARD par sa bordure périanale et par l'absence de bordure latérale festonnée. D'ailleurs le *Ps. Grimaldii* ne possède pas de papilles dorsales et a une queue très développée. De plus les corpuscules calcaires sont différents dans les deux espèces.

Si notre espèce possède des pédicelles sur le radius médian, nous devrons la rapprocher des *Psychropotes raripes* Ludwig, *Ps. buglossa* R. Perrier, *Ps. fucata* R. Perrier et *Ps. longicauda.*

Le *Ps. raripes* a une disposition des pédicelles latéro-ventraux et une structure des corpuscules calcaires assez semblables à celles de notre espèce, mais il ne possède aucune papille dorsale et ses pédicelles latéro-ventraux sont bien plus développés que ceux du *Ps. Brucei.*

Les *Ps. buglossa* et *Ps. fucata* se distinguent du *Ps. Brucei* par la forme et le nombre des pédicelles latéro-ventraux, l'allure de la région caudale, le nombre des papilles dorsales et la forme des corpuscules calcaires.

Le *Ps. longicauda* a un plus grand nombre de papilles dorsales, de quatre à cinq paires, de nombreux pédicelles latéro-ventraux, et sa région caudale se termine par deux prolongements digitiformes. Cet ensemble de caractères l'éloigne donc de notre nouvelle espèce.

## DENDROCHIROTES.

### CUCUMARIIDÉS.

#### Psolus, Oken.

*Psolus antarcticus* (Philippi).

Pour la bibliographie voir :

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1907. C. Vaney, *Holothuries : Expédition antarctique française*, p. 21.

Port Stanley, Iles Falkland ; profondeur 4 brasses. Un exemplaire.

Ce petit exemplaire est de forme elliptique ; son plus grand axe atteint 15 millimètres de longueur et le plus petit axe a 10 millimètres. La coloration est blanchâtre. Les plaques péribuccales sont beaucoup plus développées que les périanales. Le pourtour de la sole a deux rangées d'ambulacres. On distingue de petites granulations sur les grandes écailles dorsales.

#### Psolidium, Ludwig.

*Psolidium convergens* (Hérouard).

1905. R. Perrier, "Holothuries antarctiques du Muséum d'histoire naturelle de Paris," p. 38.
1906. E. Hérouard, *Holothuries : Expédition antarctique belge de la "Belgica,"* p. 13.

Janvier 1903, Port Stanley, Iles Falkland ; profondeur 4 brasses. Un exemplaire.

Cet unique exemplaire est blanchâtre ; il mesure 22 millimètres de longueur et 7 millimètres de plus grande largeur ; son extrémité postérieure est conique et légèrement relevée du côté dorsal. La disposition des pédicelles et la forme des corpuscules calcaires correspondent exactement aux descriptions d'Hérouard et de R. Perrier.

*Psolidium* (*Cucumaria*) *Coatsi*, nov. sp. (Pl. IV. fig. 47, 48, 49 et 50.)

Station 325, Baie de la Scotia, Orcades du Sud ; profondeur 9 à 10 brasses. Un exemplaire.

Le corps est presque cylindrique, mais faiblement incurvé ; l'extrémité postérieure est conique et l'extrémité antérieure est tronconique. La bouche et l'anus sont terminaux. Cet exemplaire mesure 25 millimètres de longueur et 10 millimètres de diamètre ; ses téguments sont blanc grisâtre. Les pédicelles du trivium sont localisés sur une sole ventrale aplatie mais encore un peu convexe et qui n'est pas nettement circonscrite.

Les rangées de pédicelles, bien visibles, ne semblent commencer qu'à 6 millimètres en arrière de l'ouverture buccale et se terminer qu'à 4 millimètres de l'anus, mais en réalité elles se prolongent plus en avant et plus en arrière par des rangées de pédicelles de plus petite taille. Le radius médian ventral est saillant et présente une cinquantaine de pédicelles répartis en deux rangées plus ou moins alternes ; les radius latéro-ventraux offrent aussi une cinquantaine de pédicelles répartis en deux rangées : la rangée interne a parfois un plus grand nombre d'appendices que la rangée externe ; celle-ci possède des régions dépourvues d'appendices et d'autres présentant de petits pédicelles.

La surface dorsale est plissée et les appendices s'y trouvent répartis sans ordre sur presque toute son étendue. Ces pédicelles ont la même importance que ceux du trivium. L'ouverture anale est bordée par cinq pédicelles.

Dans les téguments du corps sont de nombreuses plaques, plus ou moins imbriquées, ovales, à surface courbe et présentant de nombreuses perforations ; l'une de leurs extrémités est pourvue d'un prolongement plus ou moins épineux. Les plaques de la sole (fig. 47) sont de plus grande taille que celles de la paroi dorsale (fig. 49) On trouve aussi des bâtonnets à ramification plus ou moins arborescente (fig. 48). Les corpuscules des pédicelles ventraux (fig. 50) sont des plaques allongées et même ramifiées, à surface courbe et offrant de nombreuses perforations.

L'anneau calcaire est composé de dix pièces triangulaires de 2 millimètres de hauteur et d'un millimètre de base ; le sommet des parties radiales est tronqué, tandis que celui des interradiales est pointu. Les muscles rétracteurs s'insèrent vers le milieu du corps. La vésicule de Poli unique est vésiculeuse et a 5 millimètres de longueur. L'unique tube madréporique est court et terminé par une grande plaque madréporique. Les organes génitaux sont constitués par deux faisceaux d'une vingtaine de tubes simples, blanc jaunâtre, de 15 à 20 millimètres de longueur.

*Rapports et Différences.*—Ce *Psolidium* (*Cucumaria*) *Coatsi* pourrait être classé indifféremment dans les genres *Psolidium* ou *Cucumaria*. Pourtant il offre beaucoup d'analogie avec le *Psolidium convergens* (Hérouard) et c'est pourquoi nous en faisons plutôt un *Psolidium* qu'une *Cucumaria*. Comme le *Ps. convergens*, notre nouvelle espèce présente une sole ventrale peu différenciée et des corpuscules calcaires de la face ventrale non semblables à ceux de la face dorsale ; mais chez le *Ps. Coatsi*, les plaques sont toutes munies d'un prolongement à l'une de leurs extrémités et cette espèce ne possède que des corpuscules superficiels arborescents et aucune des cupules treillissées décrites chez le *Ps. convergens* ; de plus les pédicelles de la région dorsale ont la même importance que ceux de la sole.

Parmi les *Cucumaria*, le *Ps. Coatsi* se rapproche de nos nouvelles *C. psolidiformis* et *C. conspicua*. Ses corpuscules calcaires présentent un prolongement épineux et ressemblent à ceux des *C. Steineni* Ludwig et *C. lævigata* Verrill, mais la disposition de ses pédicelles est bien différente de celle de ces deux espèces. Notre nouvelle espèce de *Psolidium* offre aussi quelques affinités avec la *C. parva*.

THYONE, Oken.

*Thyone articulata*, nov. sp. (Pl. IV. fig. 43 et 44.)

Mai 1904, Baie de Saldanha, Afrique du Sud ; profondeur 9 à 10 brasses. Deux exemplaires,

Ces exemplaires sont fusiformes ; leurs téguments sont marron brunâtre et présentent des taches plus foncées réparties sur tout le corps, mais principalement sur la face dorsale. La bouche et l'anus sont terminaux et sont entourés d'une aire blanchâtre. Les dimensions de ces deux échantillons sont les suivantes : 20 et 45 millimètres pour leur longueur, 10 et 15 millimètres pour leur plus grand diamètre.

Les pédicelles sont répartis sur toute la surface du corps et ne présentent pas de rangées radiales distinctes. Les tentacules sont au nombre de dix. Les téguments sont peu épais et renferment de nombreux corpuscules calcaires. Ceux-ci (fig. 43) sont des bâtonnets aplatis, dont les extrémités élargies présentent généralement une grosse perforation accompagnée quelquefois d'une ou deux ouvertures de plus petite dimension. Les pédicelles ont une plaque terminale avec de nombreuses petites perforations centrales et de grandes ouvertures rayonnantes placées à la périphérie.

L'anneau calcaire (fig. 44) est très développé et atteint jusqu'à 10 millimètres de longueur. Il est composé par un grand nombre de petits articles se poursuivant en arrière par dix prolongements grêles et contournés en spirale. Chacun de ces prolongements postérieurs est formé par deux séries alternantes d'articles, juxtaposées l'une à l'autre sur les deux tiers de leur longueur, mais se séparant bien nettement vers le tiers postérieur. Dans sa partie antérieure, l'anneau calcaire offre cinq prolongements coniques interradiaux et cinq prolongements radiaires biarticulés.

Les muscles rétracteurs s'insèrent au quart antérieur du corps. L'unique vésicule de Poli a 5 millimètres de longueur ; le canal madréporique est infléchi en avant. Les tubes génitaux sont simples, jaunâtres et disposés en houppes vers le milieu du corps.

*Rapports et Différences.*—La *Thyone articulata* se rapproche de la *Thyone spectabilis* Ludwig par suite de ses corpuscules binoculaires, mais elle s'en sépare nettement par la forme de son anneau calcaire muni de longs prolongements postérieurs.

La structure de l'anneau calcaire rapproche notre espèce de la *Thyone sacellus* Selenka, mais les corpuscules calcaires sont bien différents dans ces deux formes.

CUCUMARIA, Blainville.

*Cucumaria antarctica*, Vaney.

1907. C. VANEY, *Holothuries : Expédition antarctique française*, p. 6.

Station 325, Baie de la Scotia, Orcades du Sud ; profondeur 9 à 10 brasses. Plusieurs échantillons.

Les différents exemplaires de cette espèce rapportés par la *Scotia* sont absolument identiques à ceux que j'ai déjà décrits dans les Holothuries du *Français*. Leur taille est très variable : les grands échantillons atteignent de 90 à 130 millimètres de longueur et 30 millimètres de diamètre ; les petits ont seulement une vingtaine de millimètres de longueur et une dizaine de millimètres de diamètre. La plupart sont marron brunâtre et ont les pédicelles blanchâtres. Leur couronne tentaculaire est composée de dix tentacules tous égaux, pourvus chacun d'un grand nombre de ramifications blanchâtres. Un unique exemplaire possède douze tentacules non ramifiés.

Les téguments ont une coloration qui peut varier du brun au blanc ; chez un échantillon jeune ils sont très rugueux.

Les corpuscules calcaires sont obovales avec une extrémité plus ou moins pointue, mais jamais ils ne présentent de véritable prolongement. Leurs contours sont profondément découpés ; leur surface est percée d'un grand nombre de perforations et est hérissée de petits tubercules coniques ou arrondis. Chez un échantillon de petite taille les corpuscules calcaires sont très allongés et présentent une surface hérissée d'un grand nombre d'aspérités.

*Cucumaria crocea* (Lesson).

Voir pour la bibliographie :

1898. H. LUDWIG, *Holothuries der Hamburger Magalhaensische Sammelreise*, Hamburg, p. 15–24.
1904. H. LUDWIG, " Brutpflege bei Echinodermen " ; Festschrift Aug. Weismann, *Zool. Jahrb. Suppl.* Bd. vii., p. 683–699.

17 Janvier 1905, Port Stanley, Iles Falkland ; profondeur $3\frac{1}{4}$ brasses. Nombreux exemplaires.

9 Avril 1904, lat. 51° 7′ S, long. 9° 31′ W. ; profondeur 2103 brasses. Nombreux exemplaires.

8 Janvier 1903, Port Stanley, Iles Falkland ; profondeur 4 brasses. Trois exemplaires.

Les dimensions de ces divers exemplaires sont très variables : certains sont de petite taille et atteignent seulement 5 à 6 millimètres de longueur ; tandis que d'autres ont 60 à 70 millimètres de longueur. Sur les échantillons de petites dimensions, les

pédicelles des radius du trivium sont seuls développés ; chez les grands les ambulacres dorsaux sont très petits et très nombreux, formant par leur ensemble une petite crête longitudinale.

Les téguments sont minces, translucides, de couleur blanc jaunâtre ou blanc rosé. La *Scotia* a recueilli un exemplaire de 50 millimètres de longueur auquel étaient fixés des jeunes de 8 millimètres de longueur.

### *Cucumaria discolor*, Théel.

Synonyme : *C. australis*, Ludwig.

1886. Théel, *Reports of the Challenger : Holothurioidea*, ii., p. 64.

19 Mai 1904, Baie de Saldanha, Afrique du Sud, rivage. Deux échantillons.

L'aspect général de ces deux exemplaires les rapproche des *Colochirus*. Leur corps est fusiforme à contour vaguement pentagonal. Leurs longueurs respectives sont 40 et 50 millimètres et leur plus grand diamètre 15 millimètres. La face ventrale est blanchâtre mais tachetée de bandes longitudinales brunâtres ; la face dorsale et les parties latérales sont marron brunâtre et parsemées de petites punctuations. Tous les radius n'ont qu'une double rangée de pédicelles. Les corpuscules calcaires des téguments sont très nombreux : ce sont de gros ovules treillissés, dix fois plus gros que les autres corpuscules ; ceux-ci sont de deux sortes : les uns sont des coupes à quatre perforations et présentant une douzaine de gros tubercules, les autres, plus superficiels, sont des plaques perforées, très grêles avec de petites tubérosités. Dans les pédicelles sont des corpuscules allongés, quelquefois incurvés, présentant de nombreuses perforations et quelques prolongements médians. Tous ces corpuscules rappellent ceux décrits par Théel dans sa *Cucumaria discolor*.

L'anneau calcaire est composé de dix pièces coniques de 4 millimètres de hauteur ; les pièces radiales sont plus fortes que les interradiales.

L'échantillon décrit par Théel provenait de Simon's Bay.

### *Cucumaria grandis*, Vaney. (Pl. IV. fig. 45 et 46.)

1907. C. Vaney, *Holothuries : Expédition antarctique française*, p. 12.

Station 325, Juin 1903 ; Baie de la Scotia, Orcades du Sud ; profondeur 9 à 10 brasses. Quatre exemplaires.

La *Scotia* a rapporté un assez grand nombre d'échantillons de cette espèce que nous avions établie sur un unique exemplaire recueilli par le *Français* et malheureusement traité à la formaldéhyde. Il nous est maintenant possible de compléter notre première description.

Tous les échantillons de la *Scotia* sont de grandes dimensions : leur longueur oscille

entre 70, 100 et 120 millimètres et leur plus grand diamètre est compris entre 50 et 70 millimètres.

La face dorsale est marron foncé, mais sur les parties latérales la coloration s'atténue et passe insensiblement au gris clair, qui est la couleur de la face ventrale. Les pédicelles sont blanchâtres et localisés sur les radius où ils sont disposés suivant deux rangées placées à une petite distance l'une de l'autre. Les dix tentacules sont tous semblables et offrent de courtes ramifications. Dans les régions rétractées la peau est épaisse, mais dans les parties étalées les téguments sont beaucoup plus minces et paraissent tachetés en certains points.

Aucun échantillon ne présente d'anneau calcaire. La vésicule de Poli unique est très grande et atteint 45 millimètres de longueur.

Les téguments renferment une seule espèce de corpuscules calcaires (fig. 45 et 46) : ce sont des plaques ovales, incurvées et perforées ; leur contour est irrégulier ; elles sont munies, à l'une de leurs extrémités, d'un grand prolongement offrant quelques pointes vers son extrémité libre.

Cette *Cucumaria grandis*, par suite de ses corpuscules calcaires, appartient au groupe des *Cucumaria* antarctiques renfermant dans leurs téguments seulement des plaques perforées munies d'un prolongement épineux. A ce groupe appartiennent les *C. lævigata* Verrill et *C. Steineni* Ludwig, mais la forme des corpuscules calcaires caractérise bien notre nouvelle espèce.

### *Cucumaria lateralis*, Vaney.

1907. C. Vaney, *Holothuries : Expédition antarctique française*, p. 15.

Station 325, Avril 1903 ; Baie de la Scotia, Orcades du Sud ; profondeur 9 à 10 brasses. Deux exemplaires.

Malgré quelques différences au point de vue des corpuscules calcaires, nous rapportons ces deux échantillons à notre *Cucumaria lateralis*, dont les exemplaires types avaient été recueillis par l'expédition antarctique française. La coloration des téguments et la répartition des pédicelles sont semblables à celles des types ; dans un échantillon nous retrouvons même les deux poches incubatrices, l'une latéro-dorsale droite et l'autre latéro-ventrale droite ; mais les corpuscules calcaires de ses téguments sont des plaques à nombreuses perforations mais dépourvues de tubercules. L'autre exemplaire possède de très grandes plaques ayant chacune de nombreuses perforations entre lesquelles sont placés des tubercules en grand nombre qui se développent et se rejoignent en certains points pour former les ébauches d'un second réseau de travées.

Ces deux échantillons ont respectivement 27 et 30 millimètres de longueur et 18 et 20 millimètres de diamètre.

*Cucumaria lævigata*, Verrill.

Voir pour la bibliographie :

1905. R. Perrier, *Holothuries antarctiques du Muséum d'histoire naturelle de Paris*, p. 22.
1906. E. Hérouard, *Holothuries de l'Expédition antarctique belge*, p. 12.

Banc de Burdwood, lat. S. 54° 25′, long. W. 57° 32′ ; profondeur 56 brasses. Huit exemplaires.

Ces divers échantillons ont une longueur comprise entre 11 et 24 millimètres ; leur plus grand diamètre varie entre 5 et 9 millimètres. Les tentacules, au nombre de dix, sont tous semblables et les pédicelles sont disposés, sur chaque radius, suivant deux rangées plus ou moins alternantes. Les téguments sont rugueux et blanchâtres ; ils ne renferment qu'une seule espèce de corpuscules calcaires. Ces corpuscules sont des plaques ovales, allongées, munies à l'une des extrémités de leur grand axe d'un prolongement épineux, quelquefois très court et parfois bifide. La partie élargie du corpuscule présente un grand nombre de perforations entre lesquelles sont des tubercules ; les protubérances de la région moyenne de la plaque calcaire sont de plus grande dimension que ceux des extrémités.

*Cucumaria leonina*, Semper.

Voir pour la bibliographie :

1905. R. Perrier, *Holothuries antarctiques du Muséum d'histoire naturelle de Paris*, p. 25.
1906. E. Hérouard, *Holothuries de l'Expédition antarctique belge*, p. 11.

Station 118, Port William, Iles Falkland ; profondeur 6 brasses. Sept exemplaires.
Station 118, Port Stanley, Iles Falkland ; profondeur 4 brasses. Un exemplaire.

Les exemplaires provenant de Port William ont l'apparence de *Thyone* ; ils sont blanc rosé, fusiformes ; leur longueur varie de 40 à 60 millimètres et leur plus grand diamètre est compris entre 12 et 18 millimètres. Les pédicelles semblent répartis uniformément dans toute la région médiane ; pourtant certains échantillons montrent encore de nombreuses rangées alignées suivant les radius, mais vers la région tentaculaire l'on observe, chez tous les exemplaires, que deux rangées de pédicelles par radius.

L'exemplaire de Port Stanley est de couleur grisâtre ; il a 22 millimètres de longueur et 7 millimètres de diamètre ; ses dix tentacules, tous semblables, sont brunâtres ; les pédicelles du trivium sont disposés sur chaque radius suivant deux rangées plus ou moins alternantes ; sur la face dorsale ces appendices sont disséminés.

Tous les échantillons renferment les corpuscules typiques de la *Cucumaria leonina* : des plaques ovales perforées, couvertes de forts tubercules et terminées à l'une des extrémités par un processus épineux simplement perforé et des boucles régulières à

quatre orifices et pourvues d'une dizaine de gros tubercules. Les pédicelles ont des bâtonnets aplatis, perforés, recourbés en arc, à contours irréguliers et offrant en leur milieu un prolongement plus ou moins épineux.

*Cucumaria insolens*, Théel.

1886. Théel, *Reports of the "Challenger": Holothurioidea*, ii., p. 70.

Baie de Saldanha, Afrique du Sud ; profondeur 4 brasses. Quatre exemplaires.

Ces divers échantillons ont une longueur comprise entre 15 et 30 millimètres et leur diamètre varie entre 7 et 10 millimètres. Leur coloration est tantôt d'un blanc grisâtre uniforme ou bien elle est blanchâtre sur la face ventrale et d'un brun plus ou moins noirâtre sur la face dorsale. Le corps est parfois cylindrique avec les extrémités arrondies, quelquefois il offre une région ventrale aplatie en une sorte de sole rampante et une région caudale légèrement relevée vers la face dorsale.

La répartition des pédicelles est assez variable. Les trois radius du trivium possèdent toujours chacun une double rangée de pédicelles ; ceux-ci sont quelquefois de plus petite taille aux extrémités du corps que vers la région médiane. Sur la face dorsale ces pédicelles sont ou localisés sur les radius ou plus ou moins disséminés sur toute la surface.

Les gros corpuscules calcaires ovuliformes ne sont quelquefois surmontés que d'un très court prolongement épineux ; parfois celui-ci peut même faire complètement défaut. Nous constatons tous les termes de passage entre ces ovules et les coupes avec tubérosités.

Un des échantillons, par suite de l'esquisse d'une sole ventrale, a absolument l'allure d'un *Psolidium*, les autres se rapprocheraient plutôt des *Colochirus*.

*Cucumaria psolidiformis*, nov. sp. (Pl. II. fig. 17 et 18 ; Pl. IV. fig 51, 52 et 53.)

Station 325, Juin 1903, Baie de la Scotia, Orcades du Sud ; profondeur 10 brasses. Un exemplaire.

Cet unique exemplaire (fig. 17 et 18) mesure 35 millimètres de longueur ; il est presque cylindrique avec une face ventrale légèrement aplatie constituant une sole mal délimitée ; son plus grand diamètre est de 10 à 12 millimètres. L'extrémité postérieure est conique et présente l'anus à son sommet, l'extrémité antérieure est infléchie de telle sorte que l'ouverture buccale est tournée vers la région postérieure.

Le corps est couvert sur toute sa surface de petits pédicelles assez rapprochés les uns des autres. De gros pédicelles sont répartis le long de chaque radius ; leur disposition varie d'une région à l'autre. Sur le bivium, ces séries radiales s'étendent de la bouche à l'anus et renferment vingt-cinq pédicelles par radius disposés sur deux rangées alternantes.

Sur le trivium s'est constituée une sole : les rangées de gros pédicelles ne commencent qu'à 3 millimètres de la bouche et se terminent à 5 millimètres de l'anus ; suivant le radius médian, on compte vingt-quatre de ces appendices disposés sur deux rangées alternantes et sur chaque radius latéral on trouve une cinquantaine de pédicelles très rapprochés les uns des autres et placés sur une seule rangée ; pourtant cinq à six de ces appendices, échelonnés d'un côté de cette rangée, forment l'ébauche d'une rangée externe.

L'anus est bordé de cinq papilles. La couronne tentaculaire comprend dix tentacules jaunâtres munis de nombreuses arborescences ; les deux tentacules ventraux sont plus petits que les autres.

Les téguments sont minces, blanchâtres et transparents. Ils renferment d'assez nombreuses plaques calcaires (fig. 51), à contours irréguliers, percées de plusieurs ouvertures ; des tubercules arrondis sont disséminés sur les travées. Les petits pédicelles ont des plaques terminales réticulées et de petits bâtonnets incurvés (fig. 53). Les gros pédicelles possèdent des bâtonnets ramifiés (fig. 52) ou des plaques semblables à celles des parois du corps.

L'anneau calcaire est peu développé. Il se compose de dix pièces dont la hauteur est d'un millimètre et la largeur un demi-millimètre. Les radiales offrent une pointe médiane antérieure bifide ; les interradiales, légèrement plus petites, ont une pointe médiane simple. Les muscles rétracteurs s'insèrent vers le quart antérieur du corps.

L'unique vésicule de Poli est tubuleuse et mesure 3 à 4 millimètres de longueur. Les organes arborescents s'étendent jusqu'à la région antérieure du corps, ils se composent chacun d'un tube principal portant de distance en distance quelques ramifications de grande taille.

*Rapports et Différences.*—La présence de petits pédicelles disséminés sur tout le corps et la localisation de gros pédicelles suivant des rangées radiales, nous amène à considérer la *Cucumaria psolidiformis* comme se rattachant à l'ancien groupe des *Semperia.*

Cette espèce est intéressante, car, a priori, on pourrait la considérer comme un *Psolidium* par suite de la formation d'une sole ventrale à bords marqués simplement par les rangées latérales de pédicelles. Elle semble être un terme de transition entre les deux genres *Psolidium* et *Cucumaria.* Elle doit être comparée au *Psolidium convergens* (Hérouard) et à la *Cucumaria georgiana* Lampert.

La *C. psolidiformis*, ne possédant ni coupes treillissées, ni boucles à quatre mailles et son anus étant plutôt terminal, se sépare par suite des vrais *Psolidium.* Sa sole est encore moins marquée que chez le *Ps. convergens* (Hérouard), espèce dont elle se distingue d'ailleurs par la disposition des pédicelles et par la forme des corpuscules calcaires.

La forme des plaques calcaires des téguments peut permettre un rapprochement entre la *C. psolidiformis*, la *C. georgiana* Lampert et notre *C. lateralis* et *C. attenuata*, mais ces trois dernières espèces n'ont aucune sole ventrale.

*Cucumaria conspicua*, nov. sp. (Pl. II. fig. 15 et 16 ; Pl. V. fig 67.)

Station 325, Mai 1903 ; Baie de la Scotia, Orcades du Sud ; profondeur 9 à 10 brasses. Un exemplaire.

Ce petit exemplaire a une coloration marron brunâtre, la face ventrale étant beaucoup plus claire que la région dorsale. Le corps (fig. 15 et 16) est ovale, avec une face dorsale fortement convexe et une région ventrale aplatie ; sa longueur est de 10 millimètres et sa plus grande largeur est de 6 millimètres. La bouche et l'anus sont terminaux.

A un premier examen, un peu superficiel, les pédicelles semblent seulement localisés sur les radius, certains atteignent un très grand développement et peuvent mesurer jusqu'à 5 millimètres de long. Ils présentent tous une plaque terminale de couleur foncée. Les pédicelles dorsaux sont moins nombreux et plus courts que les ventraux. Tandis que, sur chaque radius du bivium, nous comptons une dizaine d'appendices répartis sur deux rangées, alternant plus ou moins irrégulièrement l'une avec l'autre ; sur la face ventrale, le radius médian possède une vingtaine de pédicelles et chaque radius latéral en a une douzaine.

Un examen plus complet montre de nombreux petits appendices répartis sur tout le corps entre les pédicelles de grande taille ; mais ces appendices sont bien plus visibles sur la face dorsale que sur la face ventrale. Vers les extrémités anale et buccale, les papilles sont nombreuses et constituent des écailles s'imbriquant plus ou moins les unes sur les autres et terminée chacune par une petite pointe foncée.

Dans les parois du corps se trouvent des plaques calcaires (fig. 67) ovales, à contours irréguliers, à nombreuses perforations et présentant un prolongement muni de piquants. Dans les pédicelles nous n'avons jamais pu obtenir qu'un fragment de corpuscule.

Le pharynx est volumineux, ses muscles rétracteurs viennent s'insérer vers le tiers postérieur du corps. L'anneau calcaire est constitué par dix arceaux munis chacun d'un prolongement médian antérieur, plus fort dans les radiales que dans les interradiales.

L'unique tube madréporique est infléchi en avant. Les tubes génitaux simples brunâtres sont disposés en faisceaux.

*Rapports et Différences.*—La *Cucumaria conspicua* se rapproche de notre *C. psolidiformis*, car, comme celle-ci, elle est un terme de transition entre les *Psolidium* à sole ventrale peu différenciée et les *Cucumaria* du groupe des *Semperia*.

Les corpuscules calcaires de cette *Cucumaria* avec le prolongement épineux à l'une de leurs extrémités la rapprochent des *C. Steineni* Ludwig et *C. lævigata* Verrill, mais la présence de petites papilles entre les gros appendices l'en sépare complètement.

*Cucumaria aspera*, nov. sp. (Pl. I. fig. 12 ; Pl. IV. fig. 54, 55 et 56.)

Station 325, Avril 1903 ; Baie de la Scotia, Orcades du Sud ; profondeur 10 brasses. Un exemplaire.

Le corps (fig. 12) est légèrement incurvé ; il a une région centrale renflée et des extrémités légèrement atténuées. Il mesure 11 millimètres de longueur et 4 à 5 millimètres de plus grande largeur. Cet exemplaire est d'un marron jaunâtre avec une face dorsale plus foncée que la face ventrale. Toute la surface du corps est hérissée de piquants ayant l'aspect de villosités.

Les pédicelles sont localisés sur les radius en doubles rangées plus ou moins alternantes ; ils se détachent assez bien du fond par suite de leur coloration blanc jaunâtre ; dans certaines régions ils offrent deux tailles assez différentes. Le radius médian ventral renferme de vingt-trois à vingt-quatre pédicelles ; chaque radius latéral en possède une vingtaine et chacun des radius dorsaux un nombre beaucoup plus faible, une douzaine seulement. Les tentacules sont au nombre de dix ; ils sont blanc jaunâtre et présentent des ramifications très grêles ; les deux ventraux sont de plus petite taille que les autres.

Les téguments renferment de nombreux corpuscules calcaires s'imbriquant les uns sur les autres et disposés en deux couches. Ceux de la couche profonde sont des plaques ovales, à contours irréguliers (fig. 54) et à nombreuses perforations ; les corpuscules superficiels sont des tourelles (fig. 55). La base de ces tourelles est irrégulièrement ovalaire, percée d'un grand nombre d'ouvertures et supporte en son centre une tige massive présentant trois à quatre étages de perforations. Les pédicelles renferment des plaques (fig. 56) allongées, irrégulières, percées d'un grand nombre de perforations.

L'anneau calcaire est grêle et formé de dix pièces : les radiales sont quadrangulaires et échancrées en avant ; les interradiales sont triangulaires avec une pointe antérieure bien marquée.

Les muscles rétracteurs s'insèrent vers le milieu du corps ; l'extrémité fixée sur le pharynx est épaissie, celle fixée à la paroi est au contraire très grêle. La vésicule de Poli unique est tubulée et atteint 5 à 6 millimètres de longueur. Il n'existe qu'un canal madréporique qui est infléchi en arrière. L'intestin a un aspect moniliforme. Les organes génitaux sont formés de deux faisceaux d'une dizaine de tubes simples placés dans la région moyenne du corps.

*Rapports et Différences.*—La *Cucumaria aspera* se rapproche des *C. chiloensis* Ludwig et *C. tabulifera* R. Perrier par suite de ses corpuscules calcaires en forme de tourelles, mais la base irrégulière et la tige massive de ses corpuscules la distingue de ces deux espèces.

*Cucumaria croceoïda*, nov. sp. (Pl. V. fig. 64, 65 et 66.)

Station 346, 1er Décembre 1903 ; Banc de Burdwood, lat. S. 54° 25′, long. W. 57° 32′ ; profondeur 56 brasses. Un exemplaire.

Cet exemplaire est en mauvais état, la majeure partie des téguments sont pelés. Il est ovoïde et de couleur blanchâtre. Il mesure 25 millimètres de longueur et 14 millimètres de diamètre. D'après l'examen des quelques parties intactes la répartition des pédicelles rappelle celle de la *Cucumaria crocea*. Les radius dorsaux paraissent avoir trois à quatre rangées de nombreux pédicelles très courts et peu saillants, tandis que les radius ventraux et peut-être les interradius du trivium possèdent des pédicelles de grande taille munis d'une plaque terminale. Les tentacules, au nombre de dix, sont tous semblables.

Les téguments renferment de nombreux corpuscules calcaires ayant des formes assez variées mais se rattachant les unes aux autres. Certains de ces corpuscules (fig. 66) sont des bâtonnets à surface épineuse ou mamelonnée et dont les extrémités aplaties et élargies ont un certain nombre de perforations, entre lesquelles sont disséminés quelques tubercules. D'autres (fig. 65) ont la forme de plaques ovales à contours irréguliers et présentant de nombreuses perforations dont les plus grandes sont situées dans la région médiane. On trouve tous les termes de passage entre ces deux sortes de corpuscules. Les plaques terminales des pédicelles ventraux (fig. 64) sont convexes, à nombreuses perforations, entre lesquelles sont disséminés un grand nombre de mamelons.

Les muscles longitudinaux sont légèrement jaunâtres et ont un millimètre de largeur. La vésicule de Poli unique a 10 millimètres de longueur. Le canal du sable offre quelques circonvolutions et est dirigé en avant. L'anneau calcaire est composé de dix pièces d'un millimètre de largeur et ne possédant chacune qu'un prolongement médian antérieur ; le prolongement des pièces interradiales est plus grêle que celui des parties radiales. Les organes génitaux se composent de deux faisceaux de nombreux tubes jaunâtres, simples et moniliformes. Les organes arborescents sont grêles et à parois minces.

*Rapports et Différences.*—La *Cucumaria croceoïda* rappelle beaucoup la *C. crocea* Lesson ; mais les pédicelles des radius dorsaux forment des rangées plus nombreuses que dans la *C. crocea*, les interradius paraissent posséder quelques pédicelles et de plus ses téguments renferment de nombreux corpuscules calcaires.

*Cucumaria armata*, nov. sp. (Pl. V. fig. 57 et 58.)

Janvier 1903, Port William, Iles Falkland ; profondeur 6 brasses. Un exemplaire.

Le corps est ovale, un peu incurvé, avec une face dorsale bombée et une face ventrale légèrement concave. La bouche et l'anus sont terminaux. Cet exemplaire

mesure 24 millimètres de longueur et 9 millimètres de plus grande largeur ; sa coloration est blanchâtre.

Le radius médian ventral fait saillie et sur toute sa longueur se trouvent répartis une cinquantaine de pédicelles, disposés sur une seule rangée dans la région antérieure et en deux rangées irrégulièrement alternantes sur la plus grande partie du radius. Les radius latéro-ventraux présentent une disposition des pédicelles à peu près semblable à celle du radius médian, mais peut-être un peu moins nette.

Toute la face dorsale est hérissée de papilles très nombreuses ; en certains points on distingue par transparence les muscles longitudinaux.

Les téguments sont minces et plus ou moins transparents ; ils renferment de grandes plaques épaisses à contours irréguliers et à nombreuses perforations (fig. 57). Dans les espaces interradiaux du trivium ces plaques sont imbriquées les unes sur les autres. Les corpuscules calcaires des pédicelles (fig. 58) sont des bâtonnets à extrémités ramifiées, pouvant se réunir parfois pour constituer des plaques binoculaires à nombreux tubercules.

L'anneau calcaire est grêle ; il se compose de dix pièces en arceaux présentant chacune en avant une pointe médiane échancrée ; les pièces radiales sont un peu plus fortes que les interradiales. Les muscles rétracteurs s'insèrent au tiers antérieur du corps. La vésicule de Poli est unique. Les organes génitaux se composent de deux faisceaux de tubes simples, noirâtres, placés dans le tiers antérieur du corps.

*Rapports et Différences.*—La *Cucumaria armata* rappelle le genre *Colochirus* par la disposition des pédicelles du trivium en rangées radiales, tandis que ceux du bivium sont disséminés sur toute la surface dorsale, mais elle ne possède pas une région buccale pentaradiée et elle n'a qu'une seule sorte de corpuscules dans ses téguments. La présence de grandes plaques calcaires à contours irréguliers la sépare de la *Cucumaria georgiana* Lampert et de nos *Cucumaria lateralis* et *attenuata*. Elle présente aussi quelques affinités avec les *Psolidium*.

*Cucumaria analis*, nov. sp. (Pl. V. fig. 63.)

Station 326, 5 au 26 Décembre 1904 ; Baie Jessie, Orcades du Sud ; profondeur 10 brasses. Six exemplaires.

Les dimensions de ces divers échantillons varient entre 5 et 25 millimètres de longueur et 3 à 15 millimètres de diamètre. Leur corps est ovale, blanchâtre. Les pédicelles sont localisés sur les radius, où ils sont disposés suivant deux rangées par radius. Chaque rangée comprend une vingtaine de pédicelles et vers le milieu du corps, en certains points, elle présente un dédoublement. Chez un jeune échantillon, nous ne trouvons dans certaines régions qu'une unique rangée radiale. L'anus est bordé de cinq ou dix petits pédicelles. Les tentacules, au nombre de dix, sont tous semblables et possèdent des ramifications latérales assez importantes.

Les corpuscules calcaires (fig. 63) sont des plaques ovales, à contours irréguliers et présentant de nombreuses perforations. Dans les grands échantillons, ces plaques sont incurvées. Leur réseau présente parfois à la surface quelques tubercules peu saillants.

L'anneau calcaire est composé de dix pièces en chevrons, à pointe médiane antérieure bifide ; les parties radiales sont un peu plus fortes que les parties interradiales.

Les muscles rétracteurs s'insèrent vers le milieu du corps. L'unique vésicule de Poli a 5 millimètres de longueur. Les glandes génitales sont composées de deux faisceaux de tubes simples.

*Rapports et Différences.*—Cette *Cucumaria analis* est du groupe de la *C. georgiana* Lampert. La répartition des pédicelles le long des radius, la présence de cinq à dix pédicelles périanaux et la forme des corpuscules calcaires la séparent nettement des autres espèces de ce groupe. Par la disposition des pédicelles, la *C. analis* rappelle notre *C. antarctica*, mais elle s'en distingue par la forme des corpuscules calcaires.

*Cucumaria periprocta*, nov. sp. (Pl. V. fig. 62.)

Station 325, Avril 1903 ; Baie de la Scotia, Orcades du Sud ; profondeur 9 à 10 brasses. Un exemplaire.

Le corps est obovale avec l'extrémité antérieure élargie et l'extrémité postérieure tronquée. Il mesure 10 millimètres de longueur et 5 millimètres de plus grande largeur. Sa coloration générale est marron jaunâtre ; la face dorsale est de teinte un peu plus foncée que la face ventrale.

Les pédicelles sont localisés sur les radius, où ils sont disposés en deux rangées alternantes dans lesquelles on distingue de gros et de petits appendices, ces derniers étant quelquefois peu visibles. Des séries de cercles concentriques de petites papilles sont disposées de distance en distance autour de l'anus.

Les téguments renferment des plaques calcaires à contours irréguliers et à nombreuses perforations ; sur les travées sont disséminés de distance en distance des tubercules ou des piquants. Dans les pédicelles nous trouvons des plaques terminales et de petites plaques latérales assez semblables à celles des parois du corps.

L'anneau calcaire est composé de dix arceaux simples. Les muscles rétracteurs s'insèrent vers le tiers antérieur du corps. On trouve une seule vésicule de Poli.

*Rapports et Différences.*—La *Cucumaria periprocta* appartient encore au groupe de la *C. georgiana* Lampert. Elle se distingue de cette espèce par le petit nombre de pédicelles de chaque radius et par ses plaques calcaires fortes et à grand nombre de perforations. La présence de cercles concentriques de petites papilles périanales et la disposition des pédicelles la caractérisent très nettement et la séparent de nos *C. lateralis*, *C. attenuata* et *C. analis*.

*Cucumaria perfida*, nov. sp. (Pl. V. fig. 59 et 60.)

Station 325, Avril 1903 ; Baie de la Scotia, Orcades du Sud ; profondeur 9 à 10 brasses. Un exemplaire.

Cet exemplaire est de petite taille : il mesure 6 millimètres de longueur et 2·5 millimètres de largeur. Sa coloration est blanchâtre. Son corps est ovale, presque cylindrique, il est légèrement incurvé.

La couronne tentaculaire est épanouie ; elle se compose de dix tentacules allongés, dont les deux ventraux sont réduits à l'état de moignons. Les pédicelles sont localisés sur les radius. Chaque radius en renferme de huit à dix, disposés suivant deux rangées plus ou moins alternantes ne commençant qu'à une certaine distance de la région antérieure. Les appendices du bivium paraissent de plus petite taille que la plupart de ceux du trivium.

Les téguments sont rigides ; ils renferment de nombreuses plaques imbriquées les unes sur les autres et présentant chacune un grand nombre de perforations (fig. 59). Les pédicelles possèdent des bâtonnets aplatis (fig. 60) n'ayant qu'une seule perforation.

L'anneau calcaire se compose de dix arceaux. Il nous a été impossible de voir d'autres détails de l'organisation interne.

*Rapports et Différences.*—La *Cucumaria perfida* appartient aussi au groupe de *Cucumaria* antarctiques dont le type est la *C. georgiana* Lampert. Elle se distingue de cette espèce par le petit nombre de pédicelles de chaque radius et par ses plaques calcaires percées d'un grand nombre d'ouvertures et dépourvues de tubercules.

Si on la compare à notre *C. attenuata*, on voit qu'elle s'en distingue par la disposition des pédicelles et par ses corpuscules calcaires pourvus d'un grand nombre de petites perforations.

*Cucumaria secunda*, nov. sp. (Pl. V. fig. 61.)

Station 325, Mai 1903 ; Baie de la Scotia, Orcades du Sud ; profondeur 9 à 10 brasses. Un exemplaire.

Cet exemplaire est bien épanoui. Il mesure 50 millimètres de longueur et 20 millimètres de plus grand diamètre. Le corps est cylindrique avec la région postérieure distendue et arrondie, tandis que la partie antérieure est plus ou moins plissée. La coloration générale est blanchâtre.

Les pédicelles sont localisés sur les radius en rangées qui ne débutent qu'à 10 millimètres en arrière de la couronne tentaculaire et qui s'arrêtent à 5 millimètres de l'anus. Le radius médian ventral renferme une cinquantaine de pédicelles répartis pour la plupart en deux rangées plus ou moins alternes ; quelques-uns de ces appendices sont placés en dehors de ces rangées. Dans les radius latéro-ventraux, les pédicelles sont

disposés, en avant et en arrière, suivant deux rangées ; mais dans la région moyenne ils sont placés sur quatre rangées.

Les radius dorsaux offrent quatre à six rangées de pédicelles sur la plus grande partie de leur longueur, sauf pourtant aux extrémités antérieure et postérieure. L'interradius dorsal est par suite couvert de pédicelles sur un centimètre de longueur dans sa région moyenne. L'anus est entouré par de petits pédicelles.

La couronne tentaculaire se compose de dix tentacules, dont les deux ventraux sont plus petits que les autres et ne présentent à leur sommet que deux branches terminales munies chacune de quelques ramifications. La papille génitale fait saillie dans le cercle tentaculaire.

Les téguments renferment des plaques (fig. 61) imbriquées les unes sur les autres, à contours irréguliers et présentant huit à dix perforations. Un petit mamelon se trouve au centre de certaines de ces plaques. Ces corpuscules calcaires sont surtout abondants dans les pédicelles.

L'anneau calcaire se compose de dix arceaux de 5 millimètres de largeur. Chaque arceau présente une pointe médiane, de 5 millimètres, dirigée en avant ; cette pointe est simple dans les pièces interradiales et bifide pour les radiales.

Les muscles rétracteurs sont grêles et s'insèrent sur le milieu du corps. La vésicule de Poli, unique, a 5 à 6 millimètres de longueur. Les organes génitaux sont formés de deux faisceaux de tubes simples, de couleur blanc jaunâtre, atteignant 20 à 30 millimètres de longueur.

*Rapports et Différences.*—La *Cucumaria secunda* appartient au groupe des *C. georgiana* Lampert, *C. lateralis* Vaney et *C. attenuata* Vaney, dont les corpuscules calcaires sont des plaques perforées sans prolongement épineux. Dans cette nouvelle espèce les plaques sont nombreuses et imbriquées les unes sur les autres ; elles ressemblent un peu à celles décrites chez la *C. pithacnion* Lampert ( = *C. georgiana* Lampert), mais elles n'offrent qu'un seul tubercule central. D'ailleurs la disposition des pédicelles est différente de celle de la *C. georgiana* et l'anneau calcaire est bien plus fort que celui de cette espèce. Cette *C. secunda* présente quelques caractères communs avec notre *C. analis*, mais leurs corpuscules calcaires sont différents et la disposition des pédicelles n'est pas la même dans ces deux espèces ; d'ailleurs la *C. analis* a ses tentacules tous semblables, tandis que dans la *C. secunda* la couronne tentaculaire présente deux tentacules ventraux plus petits que les autres.

## EXPLICATION DES PLANCHES.

### Planche I.

| | | |
|---|---|---|
| Fig. 1. | *Benthodytes spuma*, nov. sp. | Face ventrale. Réduct. = $\frac{1}{2}$ env. |
| Fig. 2. | *Benthodytes Browni*, nov. sp. | Face dorsale. Réduct. = $\frac{1}{2}$. |
| Fig. 3. | „ „ | Face ventrale. Réduct. = $\frac{1}{2}$. |
| Fig. 4. | *Peniagone Piriei*, nov. sp. | Face ventrale. Réduct. = $\frac{1}{2}$. |
| Fig. 5. | „ „ | Vue de profil. Réduct. = $\frac{1}{2}$. |
| Fig. 6. | *Peniagone Wiltoni*, nov. sp. | Face ventrale. Réduct. = $\frac{1}{2}$. |
| Fig. 7. | „ „ | Région antérieure de la face dorsale. Gr. = 1. |
| Fig. 8. | *Euphronides Scotiæ*, nov. sp. | Face dorsale. Réduct. = $\frac{1}{2}$. |
| Fig. 9. | „ „ | Face ventrale. Réduct. = $\frac{1}{2}$. |
| Fig. 10. | *Peniagone Mossmani*, nov. sp. | Face ventrale. Réduct. = $\frac{1}{2}$. |
| Fig. 11. | „ „ | Région antérieure vue de profil. Gr. = 1. |
| Fig. 12. | *Cucumaria aspera*, nov. sp. | Vue de profil. Gr. = 2 env |
| Fig. 13. | *Psychropotes Brucei*, nov. sp. | Région antérieure de la face dorsale. Réduct. = $\frac{1}{2}$. |

### Planche II.

| | | |
|---|---|---|
| Fig. 14. | *Psychropotes laticauda*, nov. sp. | Face ventrale. Réduct. = $\frac{1}{2}$. |
| Fig. 15. | *Cucumaria conspicua*, nov. sp. | Face dorsale. Gr. = 2 env. |
| Fig. 16. | „ „ | Face ventrale. Gr. = 2 env. |
| Fig. 17. | *Cucumaria psolidiformis*, nov. sp. | Vue de profil. Gr. = $\frac{1}{2}$. |
| Fig. 18. | „ „ | Face ventrale. Gr. = $\frac{1}{2}$. |
| Fig. 19. | *Peniagone Mossmani*, nov. sp. | Région antérieure de la face dorsale. Réduct. = $\frac{3}{4}$. |
| Fig. 20. | *Benthodytes spuma*, nov. sp. | Région antérieure de la face dorsale. Réduct. = $\frac{1}{2}$. |
| Fig. 21. | *Psychropotes Brucei*, nov. sp. | Face ventrale. Réduct. = $\frac{1}{2}$. |
| Fig. 22. | „ „ | Région caudale vue de profil. Réduct. = $\frac{1}{2}$. |
| Fig. 23. | *Benthodytes recta*, nov. sp. | Face dorsale. Réduct. = $\frac{1}{2}$. |
| Fig. 24. | *Psychropotes laticauda*, nov. sp. | Corpuscules cruciformes à quatre ou cinq branches. Gr. = 300. |

### Planche III.

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| Fig. 25. | *Scotoplanes globosa*, Théel. | Bâtonnet épineux de grande taille. Gr. = 180. |
| Fig. 26. | „ „ | Bâtonnets épineux de petite taille. Gr. = 180. |
| Fig. 27. | „ „ | Corpuscule en C. Gr. = 130. |
| Fig. 28. | „ „ | Corpuscule mamelonné. Gr. = 180. |
| Fig. 29. | *Peniagone Wiltoni*, nov. sp. | Corpuscule tétraradié muni de mamelon. Gr. = 300. |
| Fig. 30. | „ „ | Corpuscule tétraradié, vu de face. Gr. = 300. |
| Fig. 31. | „ „ | Bâtonnet épineux. Gr. = 300. |
| Fig. 32. | *Peniagone Mossmani*, nov. sp. | Corpuscules cruciformes, vus de face. Gr. = 180. |
| Fig. 33. | „ „ | Corpuscule cruciforme, vu de profil. Gr. = 180. |
| Fig. 34. | *Synallactes Robertsoni*, nov. sp. | Base du corpuscule calcaire, vue de face. Gr. = 300. |
| Fig. 35. | „ „ | Corpuscule vu de profil. Gr. = 300. |
| Fig. 36. | „ „ | Bâtonnets des pédicelles. Gr. = 180. |
| Fig. 37. | *Benthodytes recta*, nov. sp. | Corpuscule cruciforme. Gr. = 300. |
| Fig. 38. | „ „ | Bâtonnets des tentacules. Gr. = 67. |
| Fig. 39. | *Euphronides Scotiæ*, nov. sp. | Corpuscules tri- et tétraradiés vus de face. Gr. = 180. |
| Fig. 40. | „ „ | Corpuscule vu de profil. Gr. = 180. |
| Fig. 41. | *Psychropotes Brucei*, nov. sp. | Corpuscule vu de profil. Gr. = 180. |
| Fig. 42. | „ „ | Corpuscules tétraradiés vus de face. Gr. = 180. |

## Planche IV.

Fig. 43. *Thyone articulata*, nov. sp. Corpuscules calcaires des téguments. Gr. = 300.
Fig. 44. „ „ Anneau calcaire. Gr. = 3.
Fig. 45. *Cucumaria grandis*, Vaney. Corpuscules des téguments vus de face. Gr. = 180.
Fig. 46. „ „ Corpuscule des téguments vu de profil. Gr. = 180.
Fig. 47. *Psolidium Coatsi*, nov. sp. Plaques calcaires de la paroi ventrale du corps. Gr. = 180.
Fig. 48. „ „ Corpuscules arborescents de la paroi dorsale. Gr. = 180.
Fig. 49. „ „ Plaque de la paroi dorsale du corps. Gr. = 180.
Fig. 50. „ „ Corpuscules des pédicelles ventraux. Gr. = 180.
Fig. 51. *Cucumaria psolidiformis*, nov. sp. Plaque des parois du corps. Gr. = 180.
Fig. 52. „ „ Corpuscules des gros pédicelles. Gr. = 180.
Fig. 53. „ „ Plaque terminale et bâtonnet des petits pédicelles. Gr. = 180.
Fig. 54. *Cucumaria aspera*, nov. sp. Corpuscules de la couche profonde des téguments. Gr. = 180.
Fig. 55. „ „ Corpuscules de la couche superficielle des téguments. Gr. = 180.
Fig. 56. „ „ Corpuscules des pédicelles. Gr. = 180.

## Planche V.

Fig. 57. *Cucumaria armata*, nov. sp. Corpuscules des téguments. Gr. = 180.
Fig. 58. „ „ Corpuscules des pédicelles. Gr. = 180.
Fig. 59. *Cucumaria perfida*, nov. sp. Corpuscules des téguments. Gr. = 180.
Fig. 60. „ „ Corpuscule des pédicelles. Gr. = 300.
Fig. 61. *Cucumaria secunda*, nov. sp. Corpuscules des téguments. Gr. = 180.
Fig. 62. *Cucumaria periprocta*, nov. sp. Corpuscules des téguments. Gr. = 180.
Fig. 63. *Cucumaria analis*, nov. sp. Plaques des téguments. Gr. = 180.
Fig. 64. *Cucumaria croceoïda*, nov. sp. Plaque terminale des pédicelles ventraux. Gr. = 180.
Fig. 65. „ „ Plaque ovale et perforée des téguments. Gr. = 300.
Fig. 66. „ „ Bâtonnets aplatis des téguments. Gr. = 300.
Fig. 67. *Cucumaria conspicua*, nov. sp. Plaques des téguments. Gr. = 180.

VANEY : Les Holothuries de l'Expédition Antarctique Nationale Écossaise.—PLANCHE I.

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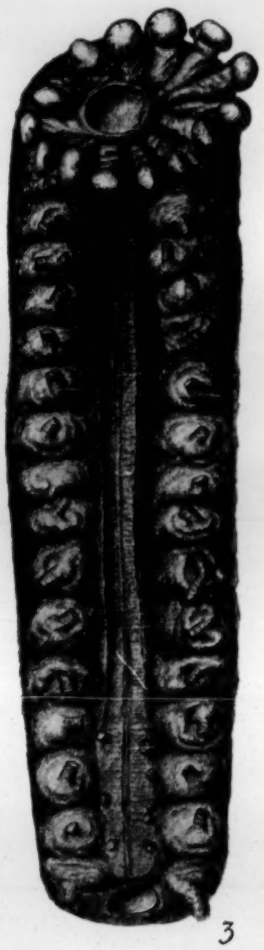
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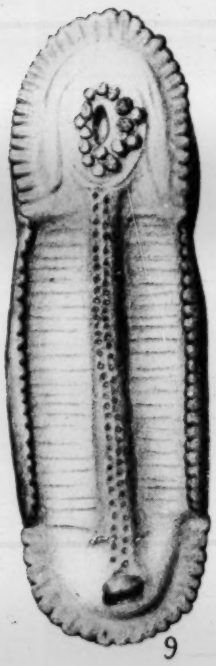
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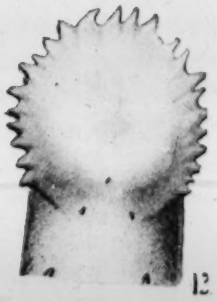
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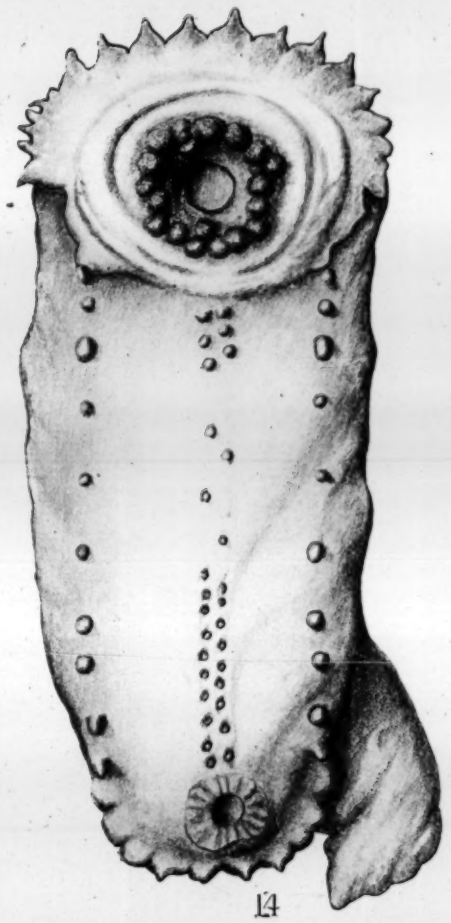
VANEY: Les Holothuries de l'Expédition Antarctique Nationale Écossaise.—PLANCHE II.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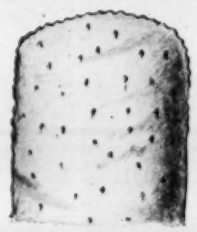
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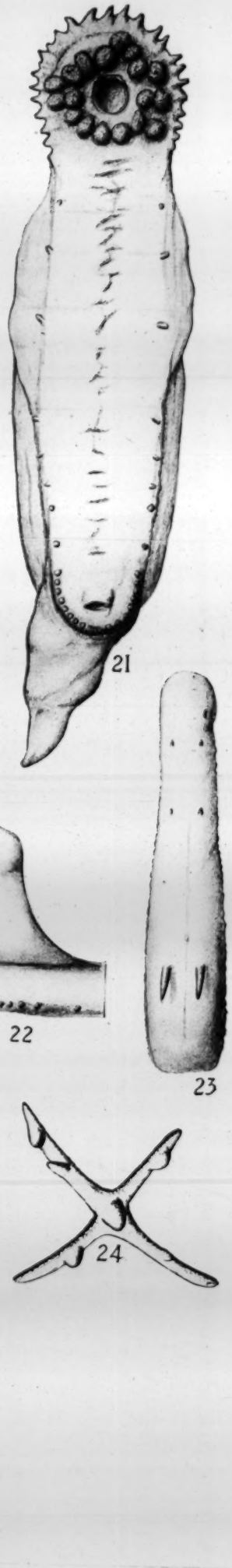
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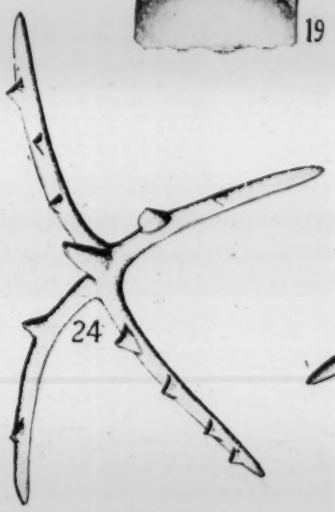
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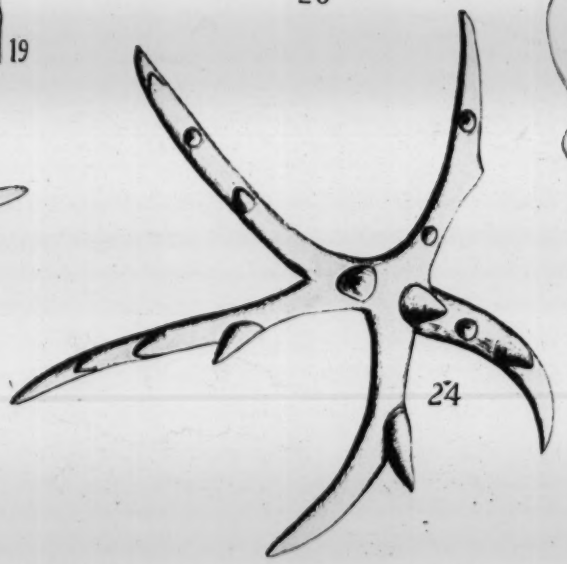
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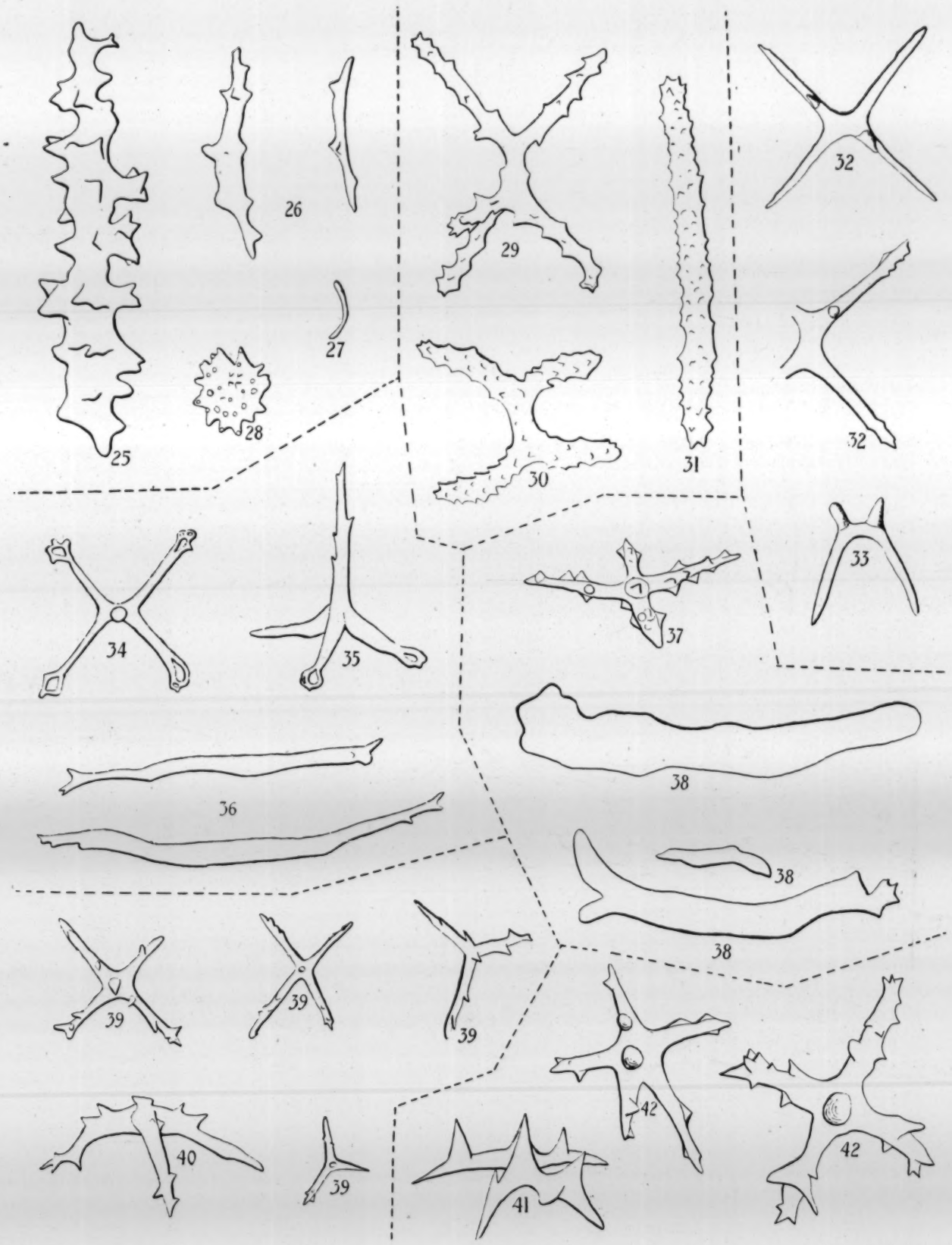
VANEY : Les Holothuries de l'Expédition Antarctique Nationale Écossaise.—PLANCHE III.



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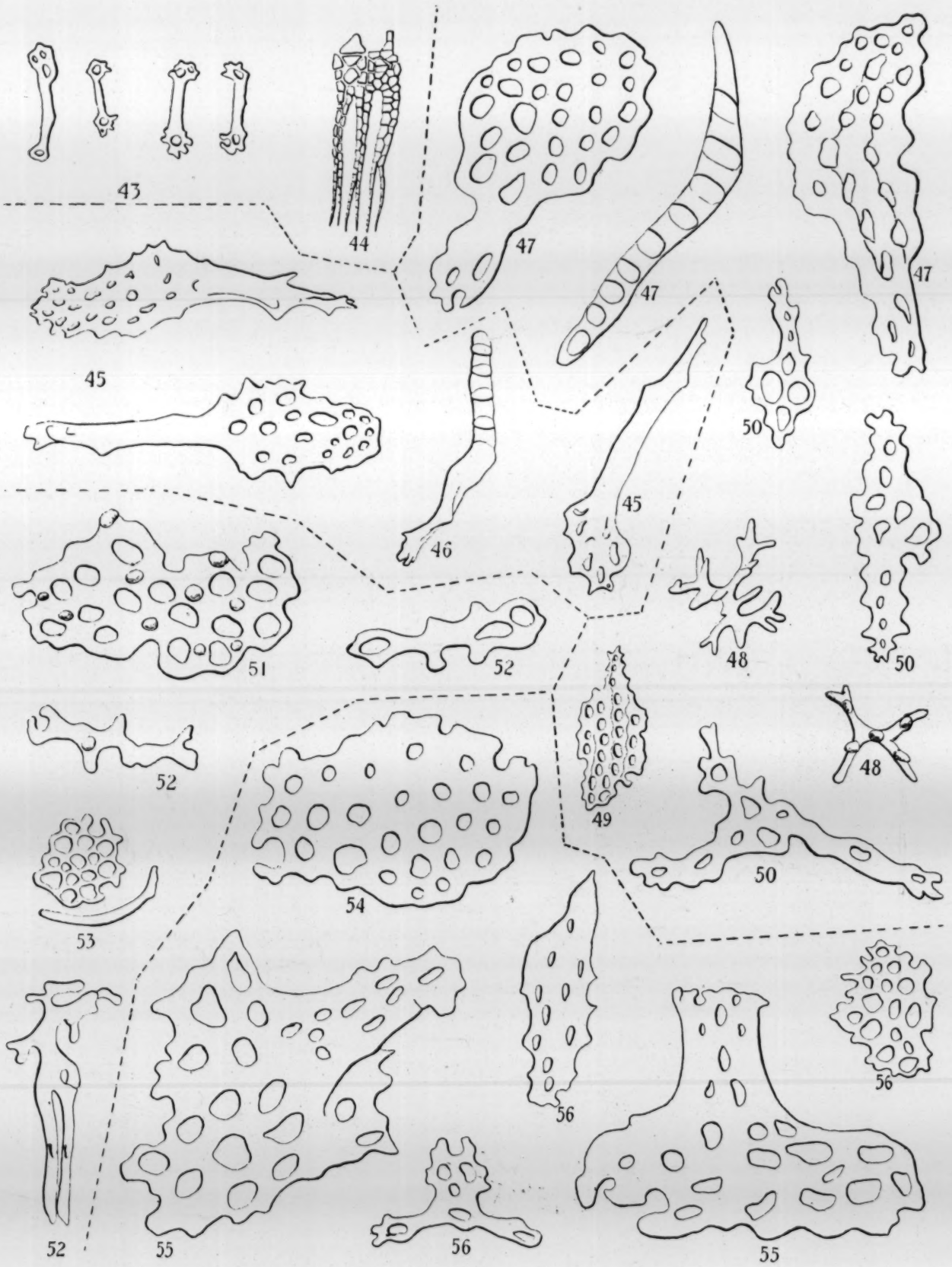

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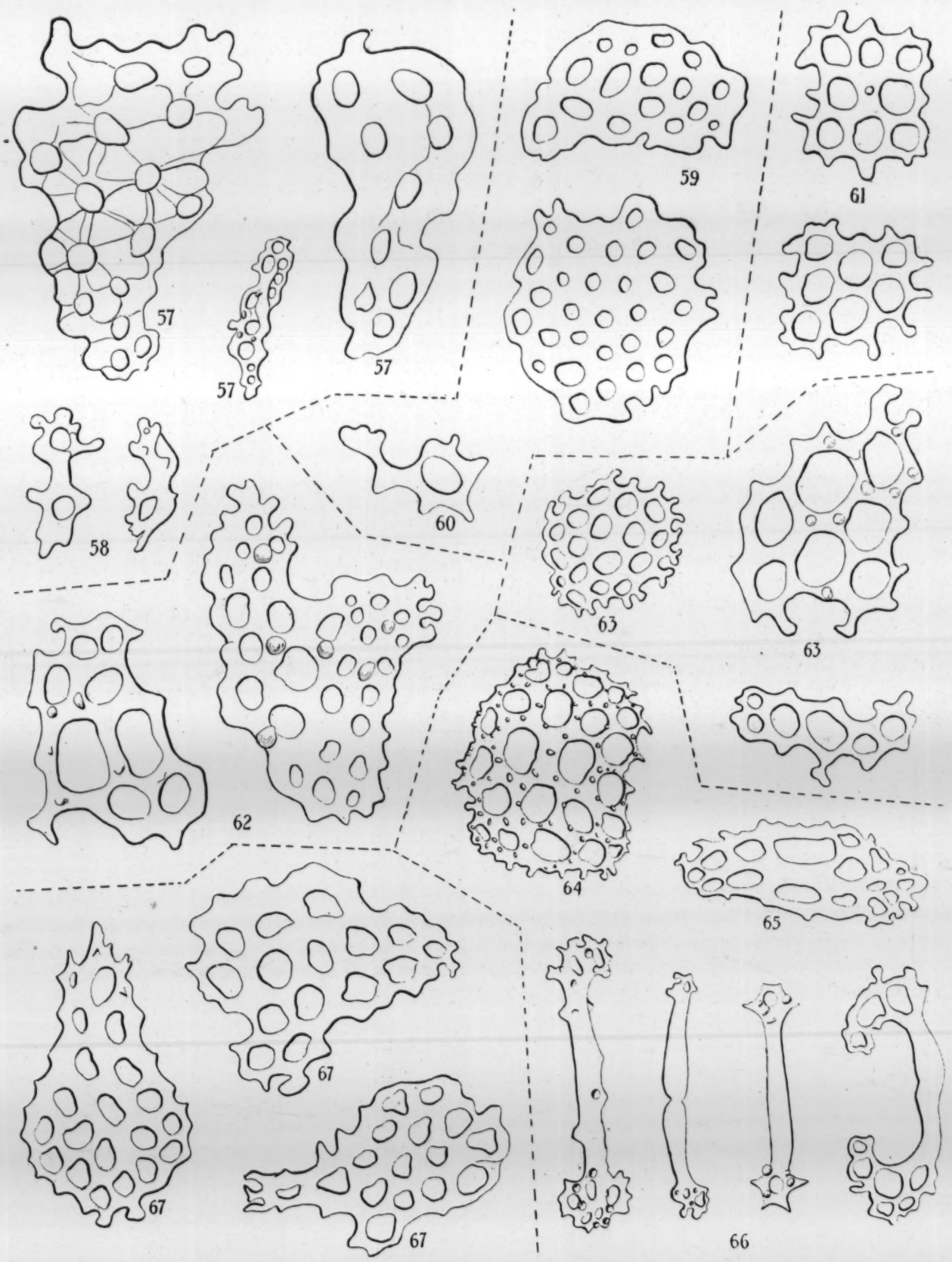

# XIX.—On Lepidophloios Scottii (a new species from the Calciferous Sandstone series at Pettycur, Fife).

By **Wm. T. Gordon**, M.A., B.Sc., Carnegie Research Scholar in Geology, Edinburgh University. *Communicated by* Professor GEIKIE, D.C.L., LL.D., F.R.S., etc. (With Three Plates.)

(MS. received April 3, 1908. Read February 17, 1908. Issued separately November 23, 1908.)

As Carnegie Research Scholar in Geology under Professor JAMES GEIKIE, D.C.L., LL.D., F.R.S., at Edinburgh University, I have entered upon a systematic examination of fossil plants from Pettycur, Fife. Though many plants have been described from this locality, nothing systematic, as far as I know, has ever before been attempted. The main objects of this research are to endeavour to connect the various strobili obtained at the locality in question with the stems on which they were borne; to describe any new species met with, and to give some account of the mode of occurrence of the material in which the plants are enclosed. Some of these objects have already been attained, but others will require further study to decide.

The material at my disposal was handed over to the University by Dr JOHN S. FLETT, H.M. Geological Survey, and has been further added to by my own collection.

The fossil to be described in the present paper occurred in a block lying loose on the shore at Pettycur. In my preliminary note I mentioned that the same fossil had been collected by Dr D. H. SCOTT, F.R.S., on 4th December 1899, and that that specimen seemed to have been on the outside of a block, and partially weathered away. In it the middle cortex—a tissue almost completely decayed in my specimens—is well preserved. From the general look also of the material from which it came, I conclude that my specimens were derived from quite a different block of the limestone. I have seen other specimens in Dr KIDSTON's collection, and Mr D. M. S. WATSON, B.Sc., tells me that there are specimens in Manchester Museum which may belong to this species; the fossil, therefore, is apparently not a rare one. Dr SCOTT's specimen does not show the complete circumference of the stem, but it must have been 25 mm. or thereby in diameter, with a central xylem cylinder of 4 mm. Unfortunately, the longitudinal sections cut from this stem are considerably out of the vertical, and do not show some very important points connected with the xylem.

The material in my own collection was all obtained from one block measuring roughly $2 \times 1 \times 1$ ft. This block split along two planes, one across and one parallel to the plane in which the stems were lying. Five stems were exposed longitudinally, and were clothed in parts with leaf-bases. Part of one of these stems and the whole of a sixth were in the third piece of the block, and from them complete tranverse sections were cut.

The whole block had a rudely bedded appearance, while the partial decay of the xylem and central cortex in one stem, and the subsequent penetration of the specimen by stigmarian rootlets (fig. 8, *a*), point to conditions of deposit similar to those present

in a swamp. In thickness the seven stems examined varied from 1 inch to 1½ inch, and the total length represented a little over 3 feet of the plant. There can be no doubt that all the stems were of the same species, as each had similar leaf-bases. The other tissues were typical of many of the Lepidodendreæ, and were therefore of no specific importance; in the case of one stem the stele had rotted away. It is not likely, however, that they all formed portions of one individual, the variation in diameter being too great for that. The region of greatest weakness in the fossil was along the inner margin of the periderm, and along this region the stems easily split; hence, as none of the specimens showed a surface view of the leaf-bases, their external form has been constructed from radial and transverse sections.

Owing to incomplete fossilization, or rather to too complete mineralisation of the tissue towards one end, the cortex was there replaced by a layer of coal from which all structure had disappeared, and the stem was useless for making sections. Most of the sections have therefore been prepared from the upper parts of the stems. I have examined nearly 180 sections of this fossil; of these 16 are from the Scott collection, Nos. 960 to 976 inclusive, and were prepared by Mr LOMAX; the rest are of my own making. The large number of my slides is due to the fact that they were cut to show certain structures, sometimes only obtained after several unsuccessful attempts. The new species described in this paper is founded on the slides mentioned in the Scott and my own collections.

The genus *Lepidophloios*, to which this plant belongs, has often been recorded from the Calciferous Sandstone series, but no example from the limestone blocks at Pettycur, showing structure, has yet been described. *Lepidophloios Scoticus*, however, was included in a list from this locality by Dr ROBERT KIDSTON, F.R.S., and Mr D. M. S. WATSON, B.Sc., has also referred to one from Burntisland.

As already mentioned in my preliminary note, I propose to call this new stem *Lepidophloios Scottii*, in honour of Dr D. H. SCOTT, F.R.S., who had collected the plant and described it in MS. some years ago. I am glad of this opportunity of showing my appreciation of Dr SCOTT's kindness in handing over to me all his material. This paper was at first intended to be a joint one with Dr SCOTT, but circumstances have led to its publication by myself earlier than was anticipated. Dr SCOTT has also acted as consultant in all matters of doubt in regard both to the present paper and to my research in general. I also desire to express my thanks to Professor JAMES GEIKIE, LL.D., D.C.L., F.R.S.; Professor I. BAYLEY BALFOUR, F.R.S.; Dr ROBERT KIDSTON, F.R.S.; and Dr HORNE, H.M. Geological Survey, for encouragement and advice in my work; to Mr ROBERT CAMPBELL, M.A., B.Sc., for aid in various matters connected with my research; and to Mr A. G. STENHOUSE, F.G.S., for assistance with the illustrative photomicrographs.

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## General Structure.

The plant of which the fragments formed parts must have been fairly tall, for, in these stems, there is no change in the various tissues throughout their length. There are slight differences between the individual pieces, chiefly as regards the amount of periderm developed.

No single section shows all the tissues in organic continuity, while some tissues, notably the phloem, are hardly to be distinguished in any section. Taken conjointly, figs. 1 and 8 give a fairly good idea of the transverse appearance, all the parts, from central xylem to the leaf-bases, being organically connected. The xylem at first sight appears solid, but careful examination reveals the presence of short, thin-walled cells distributed near the centre of the xylem, either in groups or occupying the whole of the centre (see *p*, figs. 2, 2A, and 4 respectively). Scattered through this parenchyma as detached strings of cells, or more often between the short-celled parenchyma and the long tracheides of the primary wood, are short, reticulately thickened tracheides with flat ends. In fig. 2, *t'*, the ends are shown, and in fig. 5, *t'*, these cells are cut longitudinally. These tracheides vary greatly in length, being sometimes broader than long, and occasionally they attain a length of from three to four times their width. In *Lepidophloios Scottii* the pith shows a transitionary condition between those lycopods with solid xylem and those with a true medulla. The scattered tracheides in the pith have departed less in their character from those of the primary wood than is the case in *Lepidodendron vasculare* (Binney, sp.).

The primary wood is composed of scalariformly thickened, centripetally developed tracheides (fig. 5, *t*). No secondary wood has been observed in any of the specimens, but other secondary tissue has been developed in successive zones, so that the stems are not of only one season's growth. The protoxylem is peripheral, occurring as blunt points round the woody axis. The leaf-traces have a mesarch xylem and rise abruptly at first, but, after crossing the middle cortex, they bend out horizontally into the leaf-bases (fig. 4, *l.t.*).

Owing to imperfect preservation, the phloem is distinguished with some difficulty, but a zone of partially disintegrated tissue surrounding the xylem probably represents it (fig. 1, *ph.*). Outside the phloem zone is a layer of cells tangentially elongated, probably marking the outside limit of the inner cortex. The middle cortex is well preserved only in Dr Scott's specimen (fig. 1, *m.c*), and in one of my stems near the end, and consists of thin-walled parenchyma. There is no trace of secondary tissue in this zone. The outer cortex is separated from this middle belt by a layer of tangentially elongated cells, two or three rows deep, with thin walls, which passes gradually into the thicker-walled outer cortex. The outer cortex consists of three zones, the inner being parenchymatous, the middle prosenchymatous, and the outer parenchymatous. The elements of these zones are more or less radially arranged, but the outer zone passes into a more irregular parenchyma on which the leaf-bases abut.

While there is no distinct abscission layer in the leaf-base, it breaks away at this parenchyma, which is therefore not present in stems denuded of their leaf-bases.

## Histology.

In describing the various tissues from the centre outwards, the pith naturally comes first. The stems examined are all of approximately the same diameter, and yet the pith varies greatly in amount. One stem, with primary xylem of 3·3 mm. diameter, has only a few pith cells in patches (fig. 2, *p*); another, with xylem 4·3 mm. diameter, has a pith 2·5 mm. diameter; while yet another, with xylem 3·4 mm. diameter, has a pith 1·6 mm. diameter. But even in the same specimen the pith varies greatly; the example referred to above as showing only a few pith cells in one part (fig. 2), had, in another part (about 10 cm. further down), a pith of 2 mm. diameter, and 5 cm. further up from where the section (fig. 2) was cut, the pith was 1·4 mm. diameter. In certain sections from other individuals there does not seem to be any pith at all. The pith, then, is very variable both in extent and in occurrence; its elements are slightly elongated vertically, and are arranged in vertical rows, the ends of each element being flattened horizontally. Secondary oblique walls also occur in places. The walls of these elements are thin and soft, and do not show any secondary thickening. In fig. 2*a*, *p*—the cell with no secondary thickening, but being bounded by what is the central lamella in the tracheides—is a pith cell.

Scattered through this soft parenchyma are rows of short tracheides; they occur in greater abundance towards the periphery, but are of no greater diameter than the other parenchyma cells of that tissue. These tracheides seem to form an irregular layer between the primary wood and the soft pith. They are thickened in an irregularly scalariform manner, but in some the thickenings have a tendency to assume a reticulate arrangement, whose structure is very similar to those figured by Brongniart in the description of the *Sigillaria* which he in error referred to *S. elegans*.

Occasionally also long tracheides occur isolated in the pith, and are easily distinguished from the others by their length and the scalariform thickenings on their walls. The isolated and the short tracheides are somewhat similar to those found in *Lepidodendron vasculare* (Binney, sp.) and in *Lepidodendron Hickii* (Watson).

The zone of primary wood surrounding the pith is seldom broken even when branches are given off. In one branch, however, a row of short tracheides passes out with the xylem, thus indicating a break in the wood ring, while in another case of branching, the soft pith has actually grown out of the gap thus formed in the xylem zone (fig. 6, *p*). Both these examples are in cases of unequal dichotomy. The pith cells average in dimensions ·18 × ·09 × ·09 mm.

From the measurements given of the diameter of the xylem cylinder and that of the pith, it will be seen that the primary wood is in places comparatively small in amount. In a specimen 35 mm. diameter the xylem and pith are together 4·3 mm.,

and of that the xylem forms an outer ring 9 mm. thick (about 7 or 8 tracheides). Another stem with a small pith has a wood ring 13 to 14 tracheides thick and a total xylem cylinder of 3·3 mm. diameter. Generaly speaking, the innermost tracheides are larger than those round the periphery, but this is not invariable, as small tracheides fill in the spaces between the larger ones, even in the innermost elements of the wood. The largest tracheides had a mean diameter of ·16 mm.; the smaller ones of ·07 mm. In length these tracheides vary greatly, as is shown in cases where pointed ends can be clearly seen—indicating proximity at least to the actual terminations. One of these tracheides was 5·5 mm. in length, while another was nearly 8 mm. The middle lamella can be distinctly seen in these elements both in transverse and in longitudinal sections (fig. 2, *l*, and fig. 2*a*, *l*).

The peripheral layers consist of smaller and more uniform tracheides forming a continuous ring round the whole cylinder. The contour of the wood is fairly smooth, as the protoxylem points are rounded and flat. These protoxylem teeth consist of from 9 to 10 tracheides, and the spaces between are each occupied by a leaf-trace bundle. The elements of the protoxylem are about ·02 mm. diameter, and are scalariformly thickened. In no section examined can any trace of a truly spiral protoxylem element be seen. In certain sections the branching of the xylem cylinder is well shown and will be referred to later.

External to the primary wood there is in most sections a thick band of almost completely decomposed tissue, but in one specimen this tissue is fairly well preserved. A longitudinal section shows three rows of slightly elongated parenchyma abutting on the wood, and this is probably the xylem sheath. Immediately outside this sheath there is a zone of large-celled tissue showing signs of rupture in itself; physiologically this tissue probably represents the phloem, and, wherever a branch is given off, a band of the same tissue occurs on the under side, and gradually surrounds the branch bundle. The leaf-traces do not give much help in describing this tissue, for in them the phloem representatives cannot be distinguished from the ordinary parenchyma round the bundle, except that their cells are filled with dark-coloured material. On the whole, the preservation of the tissue in the phloem region is not sufficiently good to allow of any detailed description.

Outside the phloem is a zone of parenchyma in which all the cells appear similar except the outermost layers, which are elongated tangentially. The preservation here is also very poor.

Succeeding this tissue is the middle cortex, completely preserved in one specimen only (fig. 1, *m.c.*); in others merely isolated patches appear, generally surrounding the outgoing leaf-trace. This tissue consists of thin-walled parenchyma with no definite arrangement of its cells. There is no evidence of meristematic condition in any of these cells, but in certain places they are filled with dark brown substance. It is not clear in the middle cortex how these patches of cells with dark contents are arranged, but in the outer cortex it can be seen that they occupy a definite position, and probably they

occupied a definite position also in the middle cortex. The whole zone of middle cortex in a stem 25 mm. diameter is a ring 2·3 mm. in thickness, and shows no trace of secondary growth. In none of the specimens examined can any secondary growth be seen in this middle cortex.

External to the middle cortex comes a belt, two to three cells broad, of tangentially elongated elements with thin walls; these are the inner cells of the outer cortex. These innermost cells are no larger than those of the middle cortex, but they gradually give place to larger cells with thicker walls. The tissue in this region and all the more external parts is in most cases well preserved. The outer cortex can be divided into three zones, of which the inner is composed of parenchymatous elements in no definite arrangement. Here again, however, patches of tissue filled with dark brown contents may be observed. They are seen here to occur in places well removed from the outgoing vascular bundles and also from the outer and inner edges of the parenchyma. It would seem, therefore, either that the cells secreted a resinous substance, or that they acted as storage tissue and that the brown substance represents the stored food. The inner zone stops just where the radial arrangement of the outer cortex begins, *i.e.* five or six cells in from the periderm. The brown patches are therefore confined to the area where there is no secondary growth. Beyond this, in young branches and in older ones which have no periderm, the leaf-bases would be found; in all the specimens examined, however, some secondary cortex existed. Sometimes very little appears, but in other cases there is a succession of periderm layers, denoting some sort of periodic rest and active growth (fig. 8, *pd.*).

The secondary cortex is formed by the rapid division of a belt of cells, near the outside of the primitive outer cortex. The resulting tissue is arranged in radial rows, and is more regularly arranged in vertical rows than the surrounding cortical parenchyma. Passing further out they become much elongated vertically, and in this species are filled with dark material. I cannot see any trace of secretory passages in this species, though they have been observed in others.

The dark belt is succeeded externally by long clear cells, which in turn give place to another dark zone like the last. In my specimens I cannot trace more than two of such zones, but their presence seems to indicate some sort of periodic rest. Outside the last dark peridermic ring, the cells are still radially arranged and vertically elongated, while some rows are at the same time tangentially elongated. The last two or three layers of this tissue become parenchymatous, and on this third cortical zone the leaf-bases abut. There is no distinct abscission layer, but, when the leaf-bases are absent, they have torn away this parenchyma, thus exposing the elongated elements of the secondary cortex on the denuded stem. The leaf-bases persisted even after the upper portion of the leaves had decayed, and on the shape of these leaf-bases specific characters are more safely founded than on other parts of the vegetative tissue.

Dr Kidston has shown in *Lepidophloios* that these leaf-bases pointed upwards on young twigs, and outwards and even downwards on older ones, thus indicating that these

leaf-bases continued their growth after the foliage had decayed, and that the growth was longer continued on the upper side. In all the specimens of *Lepidophloios Scottii* the leaf-bases hang downwards, and seem to have reached the limit of their growth (fig. 3).

The leaf-trace bundles, which run from the stem through the leaf-bases to the leaves, arise from the outer surface of the stele. Their xylem is derived from the protoxylem of the stele, and though their direct passage into the protoxylem cannot be traced accurately, it can be inferred. These xylem strands of the leaf-traces contain more tracheides than each individual blunt protoxylem tooth, and are situated between two adjacent protoxylems; they are probably the result of the anastomosing of parts of the protoxylem teeth between which they occur. The number of tracheides to each leaf-trace varies from 15 to 25, and the whole xylem strand is elongated tangentially with the smaller elements in the centre, *i.e.* the xylem is mesarch. The bundle has rather a steep course at first, but passes out almost horizontally through the outer cortex. By examining successive sections it is found that the xylem does not change in shape, and, even in the leaf-base, the trace retains the same form. Before passing into the periderm, however, the xylem becomes augmented by transfusion tissue, which appears to be added chiefly on the lower side of the xylem.

The phloem has mostly disappeared from the traces except in the regions of the outer cortex and the leaf-bases. In the periderm zone it is seen at its best, though even there it cannot be distinguished with certainty. It consists of slightly elongated, soft-walled tissue, but the state of preservation does not warrant further description. Passing out from the periderm, the bundle is accompanied by a parichnos strand, while round it in the leaf-base are spiral cells of the mesophyll, similar to those described in WILLIAMSON's XIX Memoir, and representing transfusion tissue. The leaf-trace passes out of the leaf-base a little below the centre of the leaf-scar, and beyond that cannot be followed, as the foliage has all decayed in the specimens examined.

The leaf-base is of considerable size, measuring $6 \times 6 \times 3$ mm., and is composed of large-celled parenchyma. It is elongated horizontally, as the measurements indicate, and is rhomboidal in section (fig. 9). The leaf-scar is about 1·7 mm. high (figs. 10 and 14, *l.s.*), and considerably broader, though the exact width of the scar has not been fully ascertained. The leaf-base assumes its greatest width about halfway between the leaf-scar and its attachment to the stem, tapering slightly in both directions. The amount of tapering is not great, but is quite distinct. Near the leaf-scar, and especially round the vascular bundle where it emerges on the scar, the large-celled parenchyma of the leaf-base gives place to a smaller-celled and more closely packed parenchyma (figs. 10 and 14).

Within the leaf-base is the ligule pit, a bottle-shaped cavity, much elongated, and lined by a layer of pallisade-like cells. This pit is placed immediately above the vascular bundle of the leaf-base, and, while long cells fill in the space between the bundle and the base of the ligule pit, no tracheides were observed among them. The ligule

arises from the base of this pit. It is tongue-shaped, and consists of uniform small-celled parenchyma. It does not quite fill the pit (figs. 10 and 14, *lg.*).

The top of the ligule pit communicates with the exterior by a short, straight canal, surrounded in places, especially near its base, by the same pallisade tissue which lines the ligule pit. This canal (fig. 10, *lg. c.*) opens far back from the leaf-scar into the space between the leaf-base and the next overlying one. In this way the opening is protected from injury and is not exposed on the outside of the plant. In all the other examples of *Lepidophloios* I have seen this canal opens near the leaf-scar and on the exposed portion of the leaf-base. The canal is oval in section, being broader than high, and the opening at the top is triangular, with the base of the triangle towards the axis of the stem.

As mentioned before, a strand of parichnos underlies the leaf-trace for the greater part of its length in the outer cortex and leaf-base. This strand is of very loosely packed, thin-walled cells; it divides into two in the leaf-base, and, rising to the level of the bundle, these two branches pass out at the leaf-scar, one on each side of the bundle. As the tissue of the parichnos is well preserved, I have been able to follow its course by both longitudinal and transverse sections. In the inner part of the periderm *no parichnos can be distinguished*, nor in any case has it been seen further in than the periderm. Fig. 11 shows the bundle *v.b.*, and on the *upper* side there is parenchyma. This section is cut near a branch, so that the traces can be seen both in the periderm and in the inner part of the outer cortex. Those in the periderm have the parichnos on the opposite side of the trace from that of fig. 11. The parenchyma above this trace belongs to the middle cortex. Passing into the periderm the parenchyma above the bundle gets less, but, a little way in, a distinct elongated portion below the bundle becomes visible (fig. 12, 2 *par.*), and this I take to be the true parichnos. As the exterior is approached this tissue increases in amount, until, just outside the periderm, it occupies the lower two-thirds of the leaf-trace (fig. 12, 1 *par.* and 3 *par.*; fig. 13, *par.*). The parichnos then communicates with the inside of the stem through the parenchymatous bundle sheath and not directly.

On entering the leaf-base the parichnos is still long and narrow, but quickly shortens and broadens into the typical kidney-shaped strand. Fig. 12 shows three leaf-traces; of these, two (Nos. 1 and 3) are near the outside of the periderm and just going to pass into the leaf-base, the third (No. 2) is further into the stem; the increase in the parichnos is well seen in these three traces.

In the leaf-base this strand can be traced quite a long distance before it forks (fig. 14, *par.*); the forking takes place just beyond a plane drawn through the opening of the ligule canal and parallel to the main axis. Sections which show any portion of either ligule or ligule canal invariably also show a single parichnos strand. Such a long stretch of unbranched parichnos is unusual. Fig. 9 shows a leaf-base beyond the region where the single strand is got, so the parichnos is represented by two masses of tissue, one on each side of the leaf-trace (fig. 9, *par.*, *par.*).

This tissue does not seem to have had any communication with the exterior other than on the leaf-scar. The examination of a large number of leaf-bases cut in all directions has failed to show any such connection either directly or by pits, as in the Lepidodendrons; indeed, the parichnos is much the same distance from the exterior at all parts of its course in the leaf-base, until it emerges on the leaf-scar.

Fig. 14 shows a radial section of a leaf-base, with parichnos strand (*par.*), leaf-scar (*l.s.*), ligule pit and ligule (*lg*). The section just misses the ligule canal, which was probably slightly bent to one side in this case, as all other radial sections show the canal as well. The point where the leaf-base ceases to be keeled and becomes round is well shown in this figure, as also in fig. 10, *c.d.*, while in fig. 7 the difference in transverse section is well marked. Fig. 7 is part of a section cut sloping outwards, so that the difference might be seen; in the lower part of the figure the leaf-bases are keeled; in the upper part they are rounded. As the lower part is nearer the stem than the upper, the leaf-bases are keeled near the stem and rounded near the leaf-scar.

The leaf-scar is slightly hollow, due probably to contraction of the tissue after the foliage had rotted away, and the leaf-trace shows as a low papilla in this hollow, about one-third of the height of the scar from the bottom.

The branching in all the cases examined was of unequal dichotomy, but apparently of two types. In most cases the wood ring is not broken, only the outer elements passing off to form the branch; but in fig. 6 the ring is ruptured, and the pith cells are seen growing out through the gap. This last type is also seen in transverse section in specimens in my own and in Dr KIDSTON's collections. The branches, however, are all alike devoid of a pith, and are representative of the "halonial" type of branch.*

In my specimens the branches project very slightly beyond the covering of leaf-bases, where they are broken over, and they seem to have been quincuncially arranged. In one series of longitudinal sections 1 inch long, there are four of these branches, so that they are set somewhat closely together; they are not in vertical rows. In all cases they are sharply broken off outside the leaf-bases, and they taper quickly to this truncation. The leaf-bases do not form rosettes round these tubercles, as is characteristic of *Lepidophloios Scoticus* (KIDSTON).

This new species has points in common with other species. The occurrence, for example, of short tracheides in and round the pith suggests comparison with *Lepidodendron vasculare* (BINNEY, sp.) and *L. Hickii* (WATSON), but the leaf-bases in these species at once differentiate them from *Lepidophloios*. The only species with which more careful comparison is necessary is *Lepidophloios Scoticus* (KIDSTON), and *Lepidodendron Pettycurense* (KIDSTON). The latter was described from the woody axis only, and the complete absence of any pith in that species is sufficient to distinguish it from *Lepidophloios Scottii*. *Lepidophloios Scoticus* is very common through the whole Calciferous Sandstone series in carbonised impressions, and, from the similarity of leaf-base, *L. Scottii* might easily be mistaken for *L. Scoticus*. Comparison is therefore very

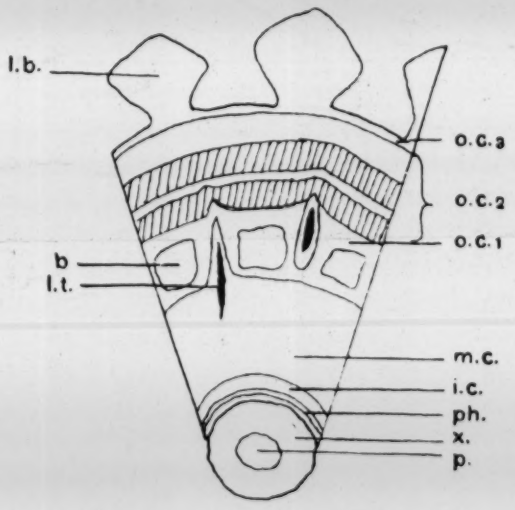
* Mr LOMAX, who prepared the sections of Dr SCOTT's specimen, referred to it as a halonia-like stem.

necessary, and I have based my comparison on the author's description. It was described from impressions, so that the specific characters depend on the leaf-bases. (Only halonial branches can be compared, as my stems are all in that condition.) In *L. Scoticus* there is a bending back of the leaf-bases round the halonial tubercules into a rosette, and the leaf-bases themselves are smooth, rounded, elongated; in *L. Scottii*, no rosettes have been observed at the base of the cone stalks, and the leaf-bases are smooth, keeled, elongated. Towards the scar the keel disappears, and from that point to the scar the leaf-base is rounded, getting flatter and flatter as the scar is approached. On the under surface of the leaf-base the ridge is more prominent than in *L. Scoticus*.

## Summary.

*Lepidophloios Scottii* occurs in the Pettycur limestone in the Calciferous Sandstone series of Fife. The species is named in honour of Dr D. H. Scott, F.R.S., and is founded on sections 960 to 976 in the Scott collection and about 180 sections in the Gordon collection. It is a true *Lepidophloios*, having all the characters of that genus. The stem is typical of the *Lepidodendreæ*, is in this case "halonial," and is clothed with leaf-bases. The leaf-trace is collateral, the xylem mesarch, and a parichnos strand occurs beneath the bundle. The cone branches have no pith, are typically halonial, and are quincuncially arranged. The main stem has a pith with short tracheides and sometimes long tracheides scattered in it. The specific characters derived from the leaf-bases, and irrespective of those derived from the structure of the stele, are as follows:—

1. The leaf-base is keeled for three-quarters of its length, and then slopes suddenly down to the leaf-scar with an unkeeled, concave surface.
2. The ligule canal is short, straight, and has its orifice covered by the overlying leaf-bases.
3. There is a pallisade-like layer round the ligule pit.
4. The parichnos only forks a short distance below the leaf-scar.




$o.c._1$ ; $o.c._2$ ; $o.c._3$ = three layers of outer cortex ; $o.c._2$ is the secondary tissue (periderm).
*m.c.* = middle cortex.
*i.c.* = inner cortex.
*ph.* = phloem (physiological).
*x.* = xylem.
*p.* = pith.
*l.t.* = leaf-trace.
*l.b.* = leaf-base.
*b.* = section of reticulum of cells with dark-brown contents.

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„ (1906), "The Present Position of Palæozoic Botany," *Progressus Rei Botanicæ*, 1907.

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## EXPLANATION OF PLATES.

Figs. 1–14. Photomicrographs by A. G. Stenhouse, F.G.S., and the author.

Fig. 2*a*. Camera Lucida drawing by the author.

Fig. 1. Transverse section of *Lepidophloios Scottii*. *x* = xylem; *ph.* = phloem; *m.c.* = middle cortex; *o.c.* = outer cortex; *pd.* = periderm; *br.* = branch. Scott Collection 965. × 5.

Fig. 2. Tranverse section of central xylem cylinder. *p* = pith; *l* = central lamella; *t′* = end of short tracheide. Gordon Collection 176. × 36.

Fig. 2*a*. Enlarged drawing of tracheides to show central lamella (*l*).

Fig. 3. Longitudinal section of stem. *x* = xylem; *m.c.* = middle cortex; *o.c.* = outer cortex; *pd.* = periderm. Gordon Collection 173. × 2.

Fig. 4. Longitudinal section of xylem cylinder. *l.t.* = leaf-trace bundle; *t* = tracheides of xylem (scalariformly thickened); *p* = pith. Gordon Collection 228. × 14.

Fig. 5. Longitudinal section of xylem. *t* = tracheide (scalariformly thickened); *t′* = short tracheide (reticulately thickened). Gordon Collection 223. × 36.

Fig. 6. Longitudinal section through a branch. *x* = xylem of main stele; *x′* = xylem of branch; *p* = pith cells growing out through gap. Gordon Collection 228. × 36.

Fig. 7. Transverse section of leaf-bases, showing keeled and unkeeled region of leaf-bases, but sloping out from the stem. Gordon Collection 216. × 2.

Fig. 8. Transverse section of stem with leaf-bases attached. *a* = stigmarian rootlet; *o.c.* = outer cortex; *pd.* 1 and *pd.* 2 = layers of periderm; *l.b.* = leaf-base. Gordon Collection 152. × 3.

Fig. 9. Transverse section of leaf-base. *v.b.* = vascular bundle; *par.* = parichnos. Gordon Collection 215. × 12.

Fig 10. Longitudinal radial section of leaf-base. *l.s.* = leaf-scar; *c.d.* = concave depression; *lg.c.* = ligular canal; *lg.p.* = ligular pit. Gordon Collection 223. × 12.

Fig. 11. Transverse section of leaf-trace bundle in inner part of outer cortex. *m.c.* = middle cortex coming out with the bundle; *v.b.* = vascular bundle. Gordon Collection 196. × 36.

Fig. 12. Transverse sections of leaf-trace bundles in the periderm. *par.* = parichnos. Gordon Collection 194. × 12.

Fig. 13. Part of fig 12. *x* = xylem; *b.s.* = bundle sheath; *par.* = parichnos. × 48.

Fig. 14. Longitudinal radial section of leaf-base. *l.s.* = leaf-scar; *lg.* = ligule; *par.* = parichnos; *c.d.* = concave depression. Gordon Collection 173. × 12.

MR WM. T. GORDON on *Lepidophloios Scottii*.—PLATE I.

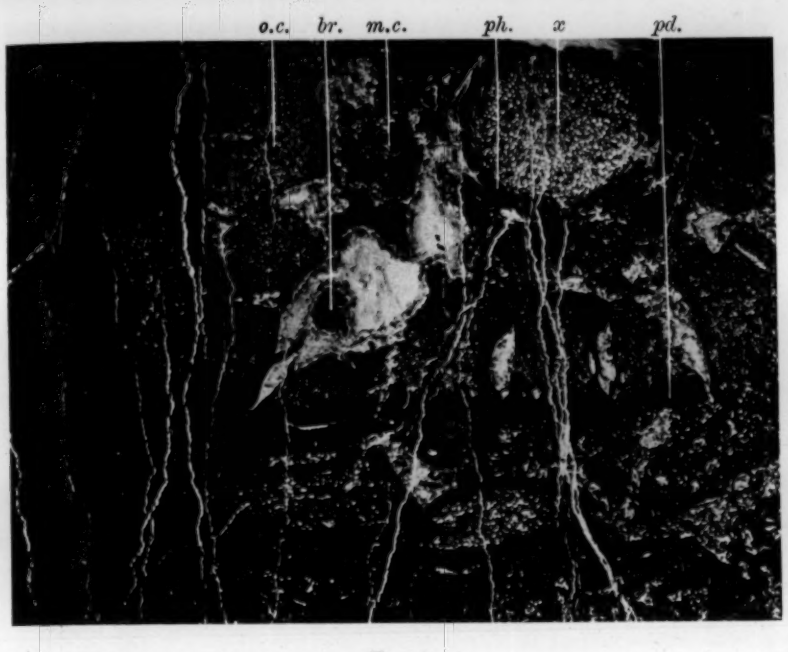



FIG. 1.

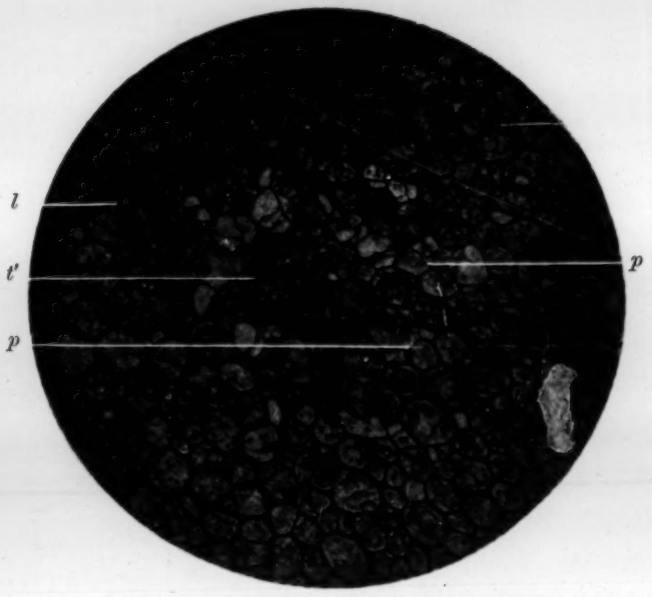



FIG. 2.

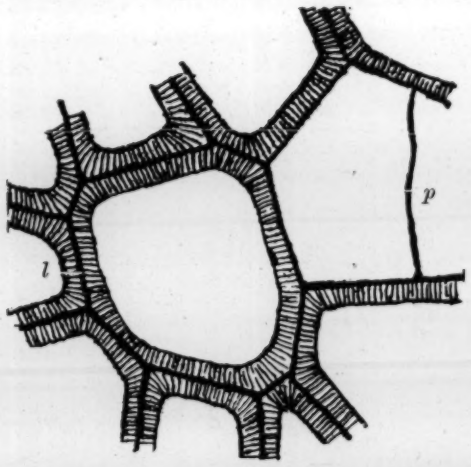



FIG. 2A.

FIG. 3.

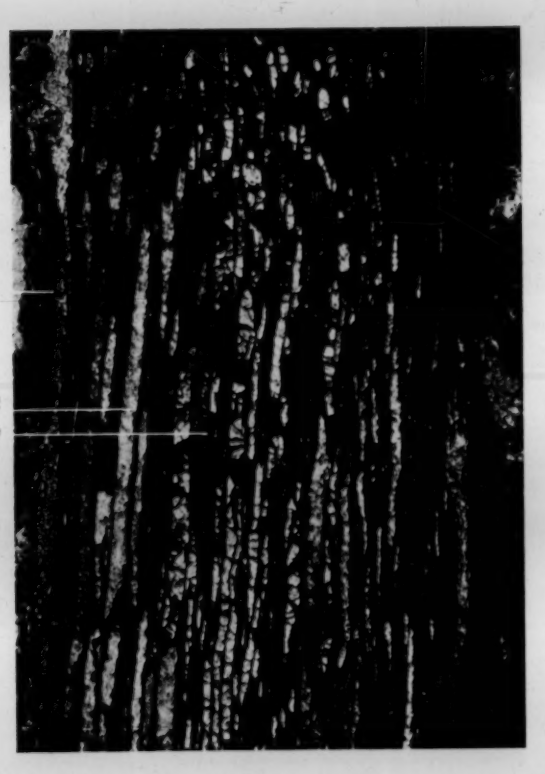



FIG. 4.

Mr WM. T. GORDON on *Lepidophloios Scottii*.—PLATE II.

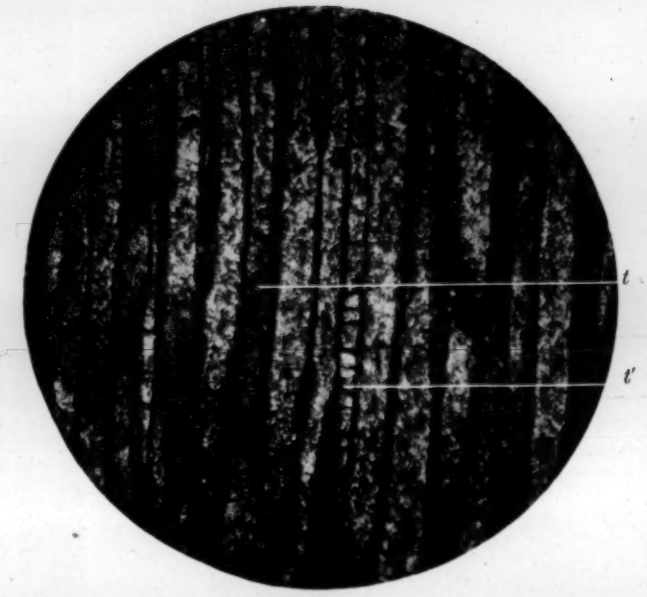



FIG. 5.

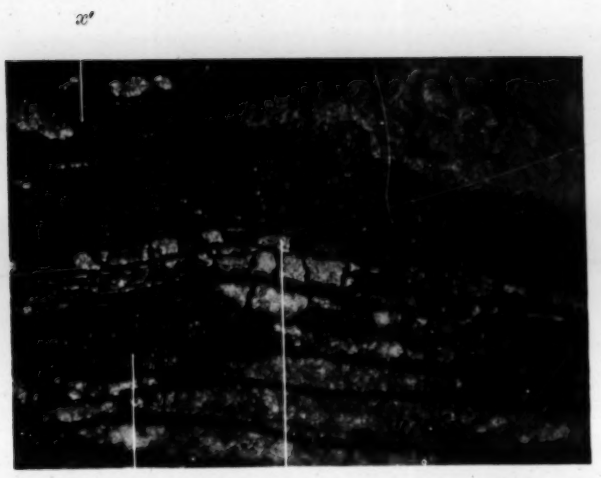



FIG. 6.

FIG. 7.

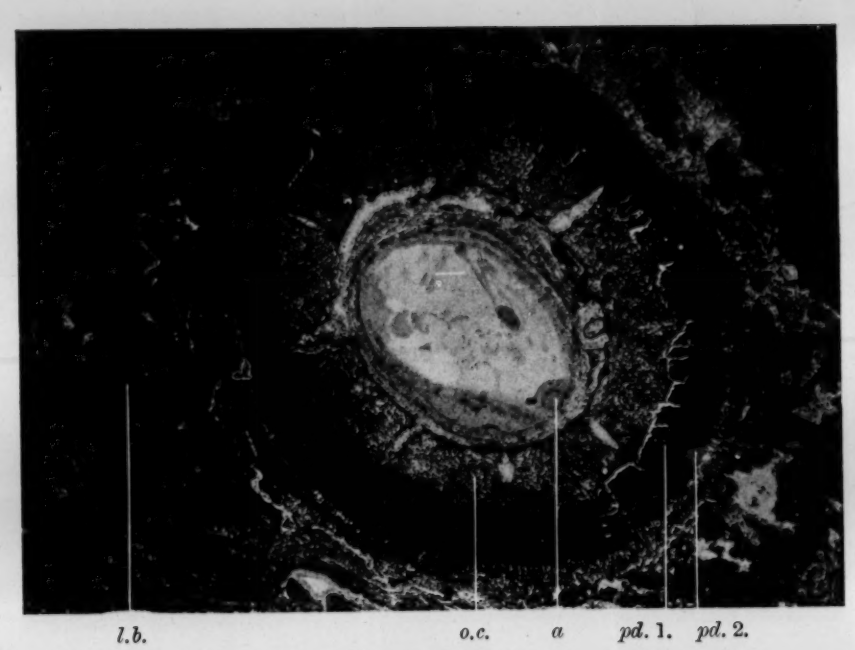



FIG. 8.

Mr WM. T. GORDON on *Lepidophloios Scottii*.—PLATE III.

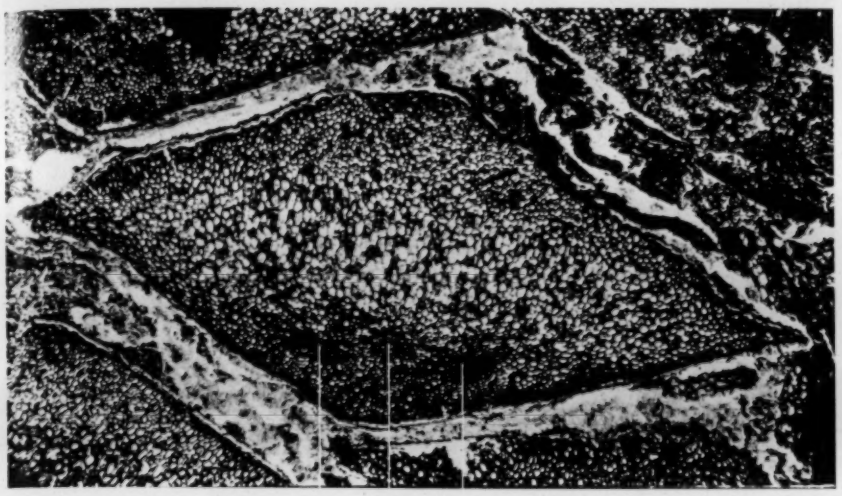



FIG. 9.

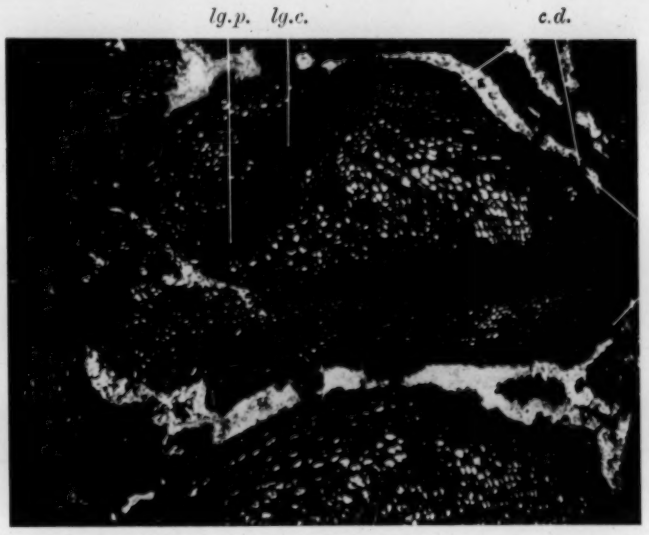



FIG. 10.

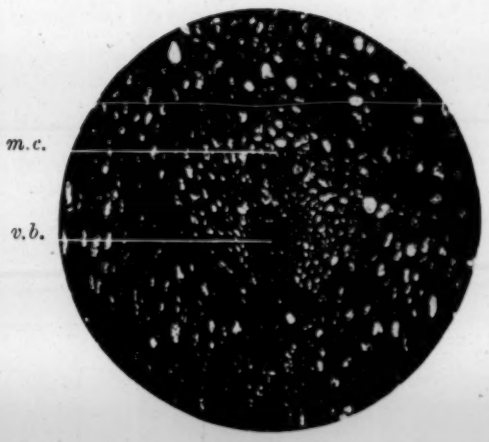



FIG. 11.

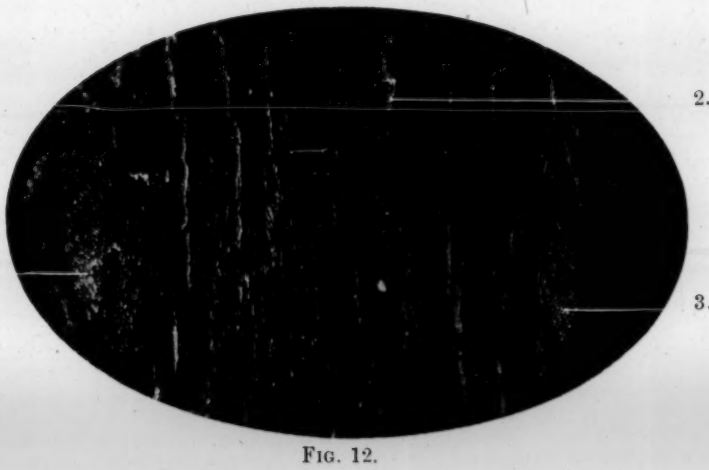



FIG. 12.

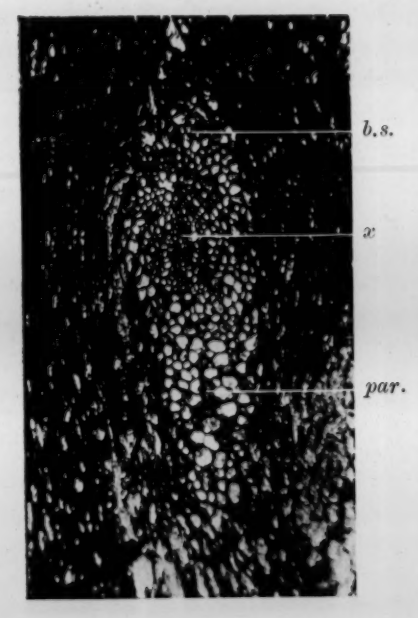



FIG. 13.

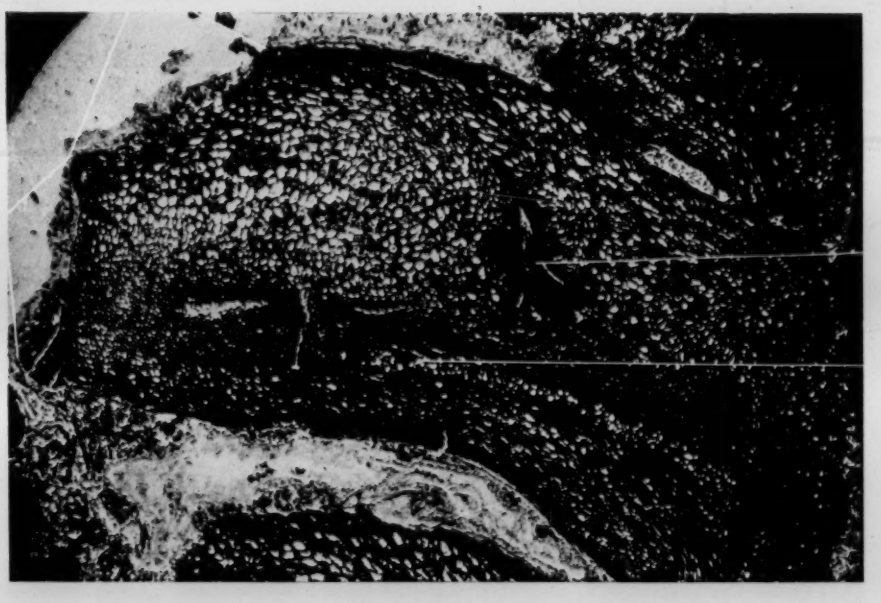



FIG. 14.

# XX.—An Investigation of the Seiches of Loch Earn by the Scottish Lake Survey.

Part III.: Observations to Determine the Periods and Nodes.—Part IV.: Effect of Meteorological Conditions upon the Denivellation of Lakes.—Part V.: Mathematical Appendix on the Effect of Pressure Disturbances upon the Seiches in a Symmetric Parabolic Lake. By Professor Chrystal.

(MS. received July 2, 1908. Read November 16, 1908. Issued separately November 24, 1908.)

## PART III.

## OBSERVATIONS TO DETERMINE THE PERIODS AND NODES.

### Determination of the Periods.

In the first part of the present series of communications * I have given a general discussion of the apparatus and methods of observation employed in the investigation of the seiches of Loch Earn, and have also mentioned some of the errors to which seiche observations are liable, and how they may be avoided or corrected. It may be useful to enumerate here certain of these errors, omitting for the most part those that arise from the construction of the instruments, and can be eliminated by proper design and by preliminary tests. We have the following, arranged more or less in what experience seems to show to be the order of their ultimate importance :—

1. Errors arising from irregularities in the rate of the driving clocks of the fixed limnographs.

2. Errors due to the hygroscopic expansion and contraction of the registering paper in the fixed limnographs.

3. Changes of phase, sudden or gradual, due to disturbances generating seiches of the same period as the one under observation.

4. Irregular displacement or blurring of the turning-points on the limnogram by wind disturbances, trains of surface waves, or seiches of very short period.

5. Uncertainty of the turning-points owing to irregular frictional lagging of the axle in the index limnographs, and also owing to the discontinuity in the reading of these instruments.

6. Displacement of the turning-points by the interference of seiches of different nodality.

7. Errors of the observers' watches.

* *Trans. R.S.E.*, vol. xlv., p. 362, hereafter quoted as *I.S.E.*

In regard to these the following precautions were used :—

1 and 2. Marks were made across the continuous limnograms every twelve hours or oftener, and the corresponding time by the observer's watch, with the date, was written opposite. The rate of the driving clock was relied upon merely for the interpolation between any required turning-point and the nearest time mark. This, of course, involved a great deal of tedious calculation and measurement of the limnograms. To give an idea of the irregularities possible from this source, it may be mentioned that the extreme variation in the number of minutes per millimetre run of the recording paper in the series of observations given in Table II. below was from ·892 on 13th August to ·903 on the following day. For the most part, however, the variation of this number in two or three days did not exceed one or two units in the third decimal place. The effect of the errors arising from the present sources is, of course, much reduced by the method of interpolation followed; and it is still further minimised by taking the weighted mean of a large number of observations.

In order to test for any possible slipping of the paper between the draw-rollers, the distance corresponding to ten revolutions of the clock arbor was always measured in the neighbourhood of the part of the limnogram under consideration. In the series of observations in Table II. the extreme variation of this number was from 651·2 to 653·6. As the variation in a period of several days was often less than a millimetre, and the variation is affected by the hygroscopic as well as the slip error, probably the latter was non-existent.

3. All stretches of the limnogram which contained any sudden change of configuration or other suspicious irregularity were rejected in the determinations of period. In using long and apparently regular series of oscillations, the series was divided into two or more parts, and the periods determined from these parts compared with each other and with the period determined from the whole. As an example, attention may be called to the fine series of 375 uninodal oscillations from 23rd to 27th September (Tables II. and III. below), which was observed both at Picnic Point and near the E. Binode. Alongside of this we may place the set of 95 uninodal oscillations observed on 4th September at the Binode (Table III.). In this last case the times of the initial and final maxima were determined independently by means of an index limnograph, the Sarasin being used merely as a counter.

4 and 5. The errors from these sources were avoided by abstaining from the use of turning-points showing zigzags or unusual flatness, and employing index limnograms taken with a narrow access tube.

6. As already explained in a former communication, errors of this kind were avoided by attending to the configuration period, using turning-points where there was symmetry in the limnogram, and, in the case of index limnograms, by using the process of residuation.*

7. The watches of the various observers were compared at short intervals with my

* *I.S.E.*, p. 382.

own, and the results entered in a time-book, from which correction curves were plotted for reducing all times to the standard of my own watch, the irregularities of which were found to be much less than other sources of error.

In the tables which follow I have grouped together observations made under similar circumstances, and deduced from each a weighted mean, thinking this the most impartial way of treating the observations, with a view both to obtain the best final result and to exhibit the degree of uncertainty of the observations. I have not taken the trouble to calculate the so-called "probable error" in each case, as I have no assured faith in this method for gauging human ignorance.

To facilitate reference to the original material in the archives of the Lake Survey, I have given the date of each observation in the first column of the table. In the second column is given the mean height of the lake-surface above an arbitrary zero on the measuring-staff. In the last column are given either the limits of error, as estimated from the measurement of the limnogram, or else the number of oscillations used in the determination. The weight in taking the mean is assumed to be inversely proportional to the estimated possible error, or directly proportional to the number of oscillations counted.

I. *Observations with Index Limnographs.*

| Date. 1905. | | Staff. Feet. | $T_1$. Minutes. | Limits of Error. Minutes. |
|---|---|---|---|---|
| June | 17 | 1·35 | 14·42 | ± ·10 |
| | 24 | 1·55 | 14·50 | ± ·10 |
| | 26 | 1·51 | 14·52 | ± ·10 |
| | 26 | 1·51 | 14·60 | ± ·07 |
| | 30 | 1·50 | 14·50 | ± ·06 |
| July | 1 | 1·40 | 14·46 | ± ·02 |
| | 8 | 1·35 | 14·45 | ± ·10 |
| | 10 | 1·35 | 14·51 | ± ·05 |
| | 25 | 1·15 | 14·59 | ± ·07 |
| | 25 | 1·15 | 14·64 | ± ·20 |
| Aug. | 7 | 2·20 | 14·58 | ± ·10 |
| | 22 | 2·40 | 14·34 | ± ·10 |

Weighted mean $T_1 = 14{\cdot}492$.

II. *Observations with the Waggon Recorder near St Fillans (Picnic Point).*

| Date 1905. | | Staff. Feet. | $T_1$. Minutes. | Number of Oscillations. |
|---|---|---|---|---|
| Aug. | 11 | 2·07 | 14·64 | 41 |
| | 13 | 1·95 | 14·30 | 19 |
| | 14 | 1·88 | 14·54 | 15 |
| | 14 | 1·88 | 14·60 | 39 |
| | 15 | 1·82 | 14·67 | 10 |
| | 15 | 1·82 | 14·56 | 46 |
| | 16 | 1·78 | 14·57 | 57 |
| | 17 | 1·72 | 14·47 | 49 |
| | 18 | 1·80 | 14·50 | 76 |
| | 20 | 2·27 | 14·55 | 65 |
| | 21 | 2·20 | 14·64 | 15 |
| | 22 | 2·30 | 14·57 | 45 |
| | 25 | 2·25 | 14·56 | 72 |
| Sept. | 2 | 1·90 | 14·58 | 38 |
| | 3 | 1·85 | 14·63 | 40 |
| | 5 | 1·83 | 14·54 | 71 |
| | 6 | 1·80 | 14·45 | 40 |
| | 17 | 2·80 | 14·49 | 30 |
| | 18 | 2·48 | 14·45 | 36 |
| | 18 | 2·48 | 14·47 | 66 |
| | 18 | 2·16 | 14·47 | 14 |
| | 18 | 2·16 | 14·55 | 30 |
| | 18 | 2·16 | 14·53 | 44 |
| | 20 | 2·00 | 14·57 | 27½ |
| | 23 | 1·82 | 14·52 | 24 |
| | 23–27 | 1·82–1·65 | 14·52 | 375 |
| | 24 | 1·80 | 14·53 | 79 |
| | 25 | 1·76 | 14·50 | 95 |
| | 26 | 1·70 | 14·53 | 100 |
| | 27 | 1·66 | 14·52 | 101 |

Weighted mean $T_1 = 14{\cdot}529$.

III. *Observations with the Sarasin (at low speed) near the E. Binode.*

| Date. 1905. | | Staff. Feet. | $T_1$. Minutes. | Number of Oscillations. |
|---|---|---|---|---|
| Aug. | 6 | 2·25 | 14·56 | 41 |
| | 7 | 2·25 | 14·47 | 42 |
| | 7 | 2·25 | 14·51 | 83 |
| | 8 | 2·15 | 14·52 | 75 |
| | 9 | 2·10 | 14·53 | 75 |
| | 20 | 2·30 | 14·62 | 48 |
| | 22 | 2·40 | 14·51 | 56 |
| | 22 | 2·40 | 14·45 | 74 |
| | 24 | 2·32 | 14·54 | 118 |
| Sept. | 1 | 2·07 | 14·55 | 30 |
| | 3 | 1·85 | 14·52 | 50 |
| | 4 | 1·87 | 14·53 | 95 |
| | 24 | 1 80 | 14·55 | 64 |
| | 25 | 1·76 | 14·49 | 106 |
| | 26 | 1·70 | 14·54 | 100 |
| | 23–26 | 1·82–1·68 | 14·52 | 270 |
| | 27 | 1·66 | 14·51 | 93 |

Weighted mean $T_1 = 14{\cdot}524$.

IV. *Observations with the Sarasin (at higher speed) near the E. Binode.*

| Date. 1905. | | Staff. Feet. | $T_1$. Minutes. | Number of Oscillations. |
|---|---|---|---|---|
| Sept. | 9 | 2·60 | 14·64 | 15 |
| | 14 | 2·60 | 14·54 | 10 |
| | 15 | 2·45 | 14·52 | 45 |
| | 16 | 2·30 | 14·53 | 10 |
| | 20 | 2·00 | 14·44 | 25 |
| | 22 | 1·87 | 14·51 | 50 |

Weighted mean $T_1 = 14·521$.

V. *Observations with Index Limnographs.*

| Date. 1905. | | Staff. Feet. | $T_2$. Minutes. | Limits of Error. |
|---|---|---|---|---|
| June | 17 | 1·35 | 8·20 | ± ·05 |
| July | 5 | 1·36 | 8·00 | ± ·03 |
| | 8 | 1·35 | 8·03 | ± ·06 |
| | 10 | 1·35 | 8·07 | ± ·02 |
| | 15 | 1·23 | 8·05 | ± ·08 |
| Aug. | 7 | 2·20 | 8·02 | ± ·04 |
| | 31 | 2·10 | 8·00 | ± ·05 |
| | 31 | 2·10 | 8·10 | ± ·10 |
| Sept. | 1 | 2·07 | 7·95 | ± ·10 |

Weighted mean $T_2 = 8·054$.

VI. *Observations with the Waggon Recorder near St Fillans (Picnic Point).*

| Date. 1905. | | Staff. Feet. | $T_2$. Minutes. | Number of Oscillations. |
|---|---|---|---|---|
| Aug. | 11 | 2·07 | 8·12 | 74 |
| | 14 | 1·88 | 8·08 | 27 |
| | 14 | 1·88 | 8·13 | 70 |
| | 15 | 1·82 | 8·15 | 18 |
| | 15 | 1·82 | 8·07 | 83 |
| | 16 | 1·78 | 8·065 | 103 |
| | 17 | 1·72 | 8·055 | 88 |
| | 18 | 1·80 | 8·06 | 138 |
| | 20 | 2·27 | 8·08 | 117 |
| | 21 | 2·20 | 8·13 | 27 |
| | 22 | 2·30 | 8·10 | 81 |
| Sept. | 2 | 1·90 | 8·15 | 68 |
| | 3 | 1·85 | 8·12 | 72 |
| | 5 | 1·83 | 8·06 | 128 |
| | 6 | 1·80 | 8·05 | 72 |
| | 18 | 2·16 | 8·10 | 25 |
| | 18 | 2·16 | 8·08 | 54 |
| | 18 | 2·16 | 8·09 | 79 |
| | 24 | 1·80 | 8·085 | 142 |
| | 27 | 1·66 | 8·086 | 169 |

Weighted mean $T_2 = 8·086$.

VII. *Observations with Index Limnographs.*

| Date. 1905. | | Staff. Feet. | $T_3$. Minutes. | Limits of Error. |
|---|---|---|---|---|
| July | 8 | 1·35 | 6·00 | ± ·08 |
| | 10 | 1·35 | 5·99 | ± ·05 |
| | 27 | 1·12 | 5·95 | ± ·01 |
| Aug. | 7 | 2·20 | 5·96 | ± ·08 |
| | 30 | 2·15 | 5·99 | ± ·02 |
| Sept. | 5 | 1·80 | 6·06 | ± ·08 |
| | 5 | 1·80 | 6·08 | ± ·08 |

Weighted mean $T_3 = 6·004$.

VIII. *Observations with the Waggon Recorder near St Fillans (Picnic Point).*

| Date. 1905. | | Staff. Feet. | $T_3$. Minutes. | Number of Oscillations. |
|---|---|---|---|---|
| Aug. | 12 | 2·07 | 6·14 | 36 |
| | 13 | 1·95 | 5·89 | 29 |
| | 21 | 2·20 | 5·91 | 45 |
| | 29 | 2·22 | 5·98 | 36 |
| | 29 | 2·22 | 6·01 | 48 |
| | 30 | 2·15 | 6·07 | 65 |
| | 31 | 2·10 | 6·00 | 60 |
| Sept. | 3 | 1·85 | 5·98 | 36 |
| | 23 | 1·82 | 6·008 | 58 |

Weighted mean $T_3 = 6·005$.

IX. *Observations with Index Limnographs.*

| Date. 1905. | | Staff. Feet. | $T_4$. Minutes. | Limits of Error. |
|---|---|---|---|---|
| Aug. | 31 | 2·10 | 4·03 | ± ·05 |
| | 31 | 2·10 | 3·94 | ± ·10 |
| Sept. | 30 | ? | 3·97 | ± ·04 |

Weighted mean $T_4 = 3·99$.

X. *Observations with Index Limnographs.*

| Date. 1905. | | Staff. Feet. | $T_5$. Minutes. | Limits of Error. |
|---|---|---|---|---|
| July | 8 | 1·35 | 3·61 | ± ·15 |
| | 27 | 1·12 | 3·45 | ± ·04 |
| Sept. | 2 | 1·90 | 3·47 | ± ·05 |

Weighted mean $T_5 = 3·48$.

XI. *Observation with an Index Limnograph.*

| Date. 1905. | Staff. Feet. | T. Minutes. | Limit of Error. |
|---|---|---|---|
| Sept. 2 | 1·90 | 1·36 | ± ·10 |

XII. *Observations with the Waggon Recorder near St Fillans (Picnic Point).*

| Date. 1905. | Staff. Feet. | T. Minutes. | Number of Oscillations. |
|---|---|---|---|
| Aug. 18 | 1·90 | 1·70 | 50 |
| 29 | 2·22 | 1·15 | 11 |
| 30 | 2·20 | 1·39 | 84 |
| Sept. 3 | 1·85 | 2·88 | 36 |

XIII. *Observations with the Sarasin, near E. Binode.*

| Date. 1905. | Staff. Feet. | T. Minutes. | Number of Oscillations. |
|---|---|---|---|
| Aug. 17 | 1·70 | 1·310 | 124 |
| 19 | 2·25 | 1·296 | 121 |
| Sept. 4 | 1·87 | 1·315 | 100 |
| 21 | 1·90 | 1·09 | 20 |

Weighted mean of first three T = 1·311

XIV. *Comparison of Calculation with Observation.*

| $\nu$. | $T_\nu$ by H.T.S. | $T_\nu$ by Du Boys. | $T_\nu$ observed. |
|---|---|---|---|
| 1 | 14·50 | 17·81 | 14·52 |
| 2 | 8·14 | 8·91 | 8·09 |
| 3 | 5·74 | 5 94 | 6·01 |
| 4 | 4·28 | 4·45 | 3 99 |
| 5 | 3·62 | 3·56 | 3·48–3·60 |
| 6 | 2·93 | 2·97 | 2·88 |
| 7 | ... | 2·55 | ... |
| 8 | ... | 2·23 | ... |
| 9 | ... | 1·98 | ... |
| 10 | ... | 1·78 | 1·70? |
| 11 | ... | 1·62 | ... |
| 12 | ... | 1·48 | 1·54? |
| 13 | ... | 1·37 | 1·36? |
| 14 | ... | 1·27 | 1·31? |
| 15 | ... | 1·19 | 1·15? |
| 16 | ... | 1·11 | 1·09? |
| 17 | ... | 1·05 | ... |

During the observations the mean level of Loch Earn varied through a range of nearly 20 inches (over 50 centimetres); but a careful examination of the Tables I.–VIII. does not appear to show any correlation between the depth of the lake and the various periods. It follows that in the case of Earn, within the range of our observations, the periods are independent of the depth.

From the theoretical point of view, there is nothing surprising in the result just arrived at. Let us consider elongated lakes of uniform breadth, and assume that the same normal curve continues to represent the lake-basin when the mean level rises or falls. For a lake whose longitudinal section is a rectangle $T_\nu = 2l/\nu\sqrt{(gh)}$. Hence, since in this case $l$ is constant, as $h$ increases all the periods diminish. If the longitudinal section is parabolic, then $T_\nu = \pi l/\sqrt{\{\nu(\nu+1)gh\}}$.* In this case $l$ is proportional to $\sqrt{h}$; hence all the periods are independent of the depth of the lake. It is easy to see from the analysis in *H.T.S.*, p. 628, that the same is true for a biparabolic lake. If the longitudinal section be rectilinear and symmetrical, shelving at both ends, then $T_\nu = 2\pi l/j_\nu\sqrt{(gh)}$.† In this case $l$ is proportional to $h$, and $j_\nu$ is a mere number depending only on the nodality; hence $T_\nu$ is proportional to $\sqrt{h}$—that is to say, all the periods increase when $h$ increases. Generally speaking, we may expect the rise of the mean level in a lake to increase its periods if the rise greatly increases the horizontal surface of the lake; and to decrease the periods, if the rise increases the horizontal surface very little. It appears from the observations of Forel‡ and Ebert§ that the Lake of Geneva and the Starberger See belong to the latter category; and Halbfass‖ has found that the Madü See belongs to the former. Loch Earn occupies an intermediate position; the constancy of its periods is therefore an indication that the assumption of a biparabolic normal curve is a good first approximation.

If it be admitted that the periods are independent of the depth, the process of taking means in Tables I.–VIII. is logically unobjectionable; and, as the identity of the uninodal, binodal, and trinodal seiches was fully established by phase observations, it only remains to select what on the whole appear the probable results of observation for $T_1$, $T_2$, $T_3$. Taking all the circumstances into account, I incline to the values

$$T_1 = 14{\cdot}52, \quad T_2 = 8{\cdot}09, \quad T_3 = 6{\cdot}01.$$

The identification of the periods in Tables IX. and X. as quadrinodal and quinquinodal respectively rests merely on the comparatively close agreement of the numbers in each table with each other and with the quadrinodal and quinquinodal periods deduced from the hydrodynamical theory and from Du Boys' formula. No phase observations were available to assist the identification.

* *H.T.S.*, p. 622. † *H.T.S.*, p. 638.

‡ *Le Léman*, t. ii., p. 122.

§ "Periodische Seespiegelschwankungen beobachtet am Starnberger See," *Sitz. Ber. kgl. bayer. Akad. d. Wiss*, Bd. xxx. (1900), p. 453.

‖ "Stehende Seespiegelschwankungen im Madüsee in Pommern," *Zeitschrift für Gewässerkunde*, Bd. vi., p. 95.

There is still greater uncertainty regarding the periods in Tables XI.–XIII., most of which rest only on a single series. Possibly T = 2·88 is the sextinodal period. It must, however, be borne in mind that the smaller the period the greater is the danger of confusion with progressive wave disturbances, with possible transversal seiches, or even with secondary local oscillations due to indentures in the shore of the lake.

## Determination of the Nodes.

The difficulties anticipated * in determining the nodes by direct observation were more than realised in practice. When the range of the seiche is large, there is nearly always a great deal of wind-embroidery of an irregular character, which it is impossible to eliminate either by damping the limnograph or by residuating the limnogram. Also, where the amplitude is small, there is almost always an aperiodic variation of the lake level, probably due to the heaping up of the water on the shallow shore, an effect which will vary with the slope of the beach. The varying slope also affects the range of the seiche to an extent which it would be difficult to calculate with any degree of accuracy. Both these causes introduce uncertainty in the method of observing with index limnographs on two sides of the node where the seiche is found in opposite phases, and then deducing its position by interpolation. A mere null method would scarcely lead to a satisfactory result, unless under exceptional circumstances which did not occur during our observations. Of the many attempts made, only a few led to limnograms which could be utilised; and in every case the curves had to be purified by residuation.

*Uninode.*—The two best pairs of observations gave almost exactly the same position for the southern end of the uninode, and led to the conclusion that it lies about 105 yards west of the position given in my paper on the Calculation of the Periods and Nodes of Lochs Earn and Treig.† This is precisely what was expected, as the actual normal curve (*C.*, p. 825) rises above the assumed biparabolic curve on the west and falls below it on the east of the calculated position of the uninode. It would be useless to calculate what the amount of divergence ought to be; because the uncertainty of one of these determinations, as shown by the observations themselves, is ±65 yards, and of the other ±129 yards, the latter being more than the divergence itself. The exact agreement of the two determinations is probably an accident.

*Eastern Binode.* — Two determinations agreed almost exactly in placing the Eastern Binode about 117 yards west of the calculated position; but the uncertainty of these determinations was ±94 yards in the one case and ±59 yards in the other.

*Western Binode.*—The best pair of observations gave a position for the southern end of the Western Binodal line 305 yards west of the calculated position. A divergence in this direction was to be expected from the shape of the true normal curve in the neighbourhood; but the amount is somewhat surprising. There can be little

* *Trans. R.S.E.*, vol. xli., p. 850.

† Henceforth referred to as "*C.*"

doubt of the correctness of the observation, because it was confirmed by another pair of observations, one made almost exactly at the position above indicated, the other 250 yards farther east. The latter gave on residuation a well-marked binodal seiche, the former none that could be recognised.

*Eastern Trinode.*—The best observation available places the southern end of the Eastern Trinodal line 88 yards west of the calculated position. The uncertainty of the determination, however, exceeds 120 yards; so that we cannot say for certain whether the actual trinode is really west or east of the calculated position; from the shape of the normal curve we should expect a considerable divergence to the east.

*Middle Trinode.*—Unfortunately, the observations for the determination of the Middle Trinode were rendered useless by casual wind-disturbances.

*Western Trinode.*—No observations of sufficient accuracy are available.

## PART IV.

## EFFECT OF METEOROLOGICAL CONDITIONS UPON THE DENIVELLATION OF LAKES.

### General Character of the Seiches on Loch Earn.

Owing to the comparatively regular shape of its basin and the fact that the depth is considerable compared with the length, the seiches on Loch Earn are very regular and very persistent. Also, probably because its longest axis is more or less parallel to the paths of the major and minor atmospheric disturbances,* Earn is very rarely free from seiches. During 1070 hours, from 10th August to 28th September, the Waggon recorder at Picnic Point was almost constantly in action; yet only $2\frac{1}{2}$ hours of calm † were recorded. During 1350 hours, from 12th October to 7th December, while the Waggon recorder was in action at Lochearnhead, there were in all about 90 hours of calm. Of these, 81 hours were made up by continuous stretches of $21^h$, $37^h$, and $23^h$ on 4th, 16th, and 20th November.

The greatest ranges observed in August and September were 79 mm., 66 mm., 73 mm., 55 mm., 55 mm., 63 mm., on 19th and 21st August and 3rd, 7th, 8th, and 9th September. Only one very exceptional range was observed between 12th October and 7th December, viz. 55 mm. on 7th December.

The range of the seiche at St Fillans is usually over 10 mm. A rough estimate showed that during the 1070 hours of observation at Picnic Point the range of the seiche was over 30 mm. during 214 hours; and during the 1350 hours at Lochearnhead it was over 30 mm. during 57 hours only. It follows that, whether we test by hours of calm, by hours of excess over 30 mm., or by occurrence of exceptional ranges, the period

* See my paper, "On the Theory of the Leaking Microbarograph, etc.," *Proc. R.S.E.*, vol. xxxviii., p. 454 (1908).

† *I.e.* whole range of seiche less than 2 mm.

from 12th October to 7th December showed much less seiche activity than the period from 10th August to 28th September.

In more or less settled weather, by far the commonest seiche configuration on Earn is a uninodal and binodal dicrote.* This varies between the two extremes where the binodal on the one hand and the uninodal on the other are scarcely noticeable; but the seiche in our observations was hardly ever either purely uninodal or purely binodal. In these seiches the 5–9– configuration period caused by the interference of the uninodal

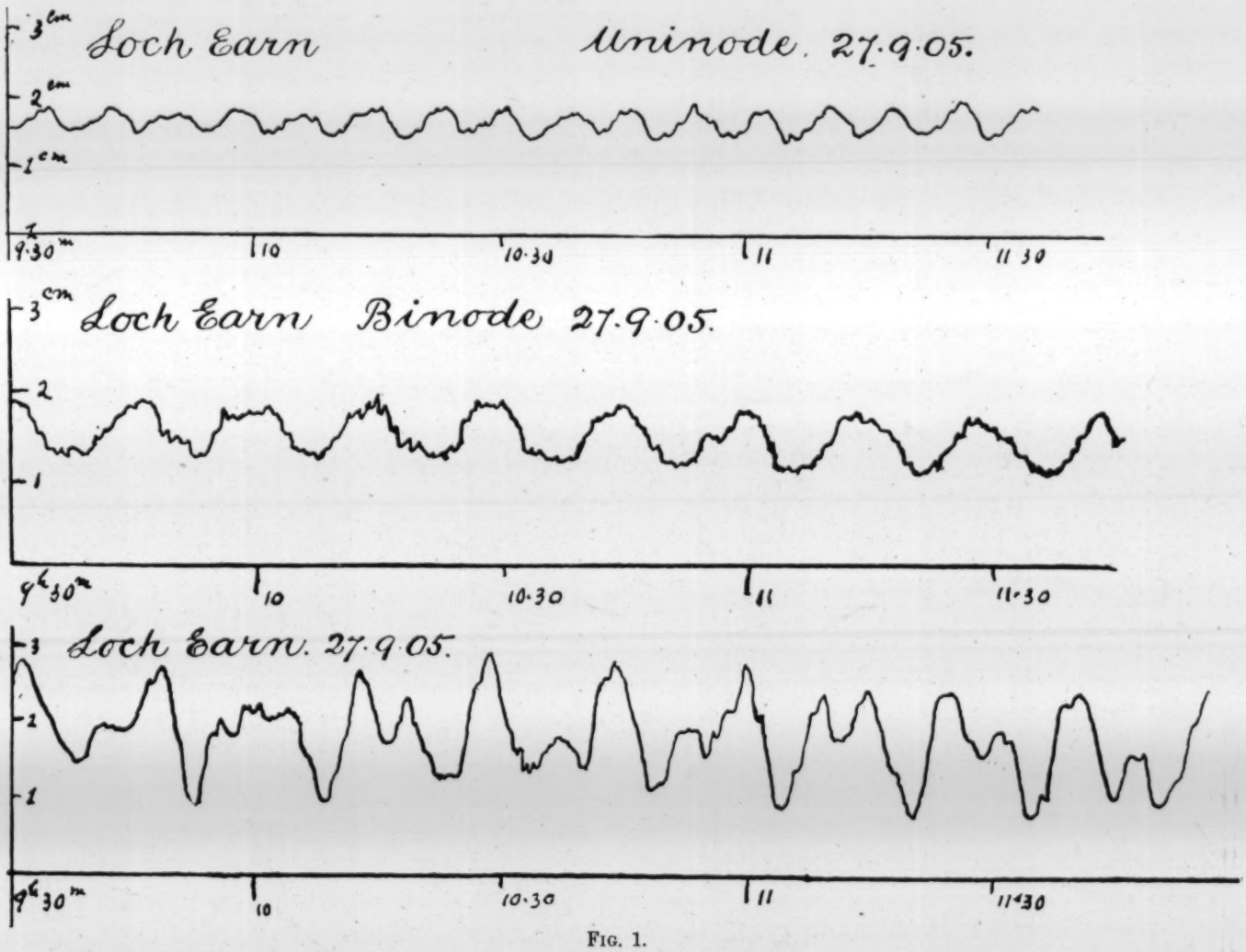



FIG. 1.

and binodal components is usually reproduced with the most beautiful regularity, sometimes for a whole day or even longer. For example, in the seiche observed at Lochearnhead from 16th to 22nd October 1905, which lasted about $6\frac{1}{2}$ days, say for 127 configuration periods, only six of these periods were found too short by one uninodal, and three too long by the same amount. It is probable that the gradual change of phase accompanying the rise and fall of the amplitudes of the components more than com-

* For brevity, in what follows we shall denote such a seiche by "UB-dicrote." Similarly, "UBT-tricrote" would mean a tricrote seiche with uninodal, binodal, and trinodal components; and we shall occasionally denote the amplitudes (half ranges) of these components by U, B, T respectively.

pensated for the fact that 9/5 is not so close an approximation to $T_1/T_2$ as is the sixth convergent, 70/39.

In times of storm or even moderate wind there is of course a strong embroidery of various kinds; but usually the UB-dicrote configuration can be seen through all the confusion, and it soon becomes the prominent feature when the weather begins to settle.

At this point we may indicate how the lake can be made to analyse its own seiches. Fig. 1 shows three simultaneous limnograms, the lowest one taken at the Picnic Point, about 480 yards from the eastern end of the lake, the middle one taken near the binode, the uppermost one taken near the uninode. All three are somewhat embroidered by the wind, but the St Fillans seiche is a UB-dicrote, the middle one a nearly pure uninodal, and the uppermost one a nearly pure binodal. The figure is at once an interesting confirmation of FOREL's theory and a verification of the approximate accuracy of the mathematical theory of Loch Earn regarded as a biparabolic lake.*

## COMPARISON OF EARN WITH TAY AND LUBNAIG.

The seiches on Loch Tay present the strongest possible contrast to the seiches of Earn. No clear dicrote or other easily recognisable configuration is ever seen. Often it is not easy even to recognise the uninodal seiche. The contrast may be partly realised by looking at the two pairs of limnograms in fig. 2. In the first pair is seen the beginning of the long seiche on Earn above mentioned, alongside of the simultaneous seiche on Tay—which was the most regular one found on that lake between 4th October and 9th November 1905. The second pair is the end of the long seiche on Earn with the simultaneous one on Tay, whose irregularity is typical.

As yet our knowledge of the seiches and meteorological conditions of Loch Tay is not sufficient to enable us to explain this difference; but we may point out here that Loch Tay is relatively a shallower lake than Earn; it is more crooked; and the relation of its axial line to the path of the minor atmospheric disturbances is different.

This divergence of conditions occurs in an exaggerated form in the case of Lubnaig, which is very shallow, has a very irregular basin, and lies across the path of the atmospheric disturbances. Accordingly, we found only four cases in which we could recognise a definite seiche in Lubnaig, having a period of about 24 min.; and in each case only a few undulations could be counted. One of these seiches is shown in fig. 3. During the rest of the six weeks of observation nothing was found but wind-embroidery and sub-permanent wind denivellation, such as would be naturally expected in a shallow lake. About this negative result there seems to be little room for doubt,

* The following method of roughly analysing a dicrote seiche which is tolerably pure and shows the 5/9 configuration may be mentioned here. If $y_0$ be the *minimum minimorum* of the ordinates of the limnogram, $y_1, y_2, y_3$ the ordinates at distances $\frac{5}{8}T_1$, $\frac{5}{4}T_1$, and $\frac{5}{2}T_1$ from $y_0$, and if A be the ordinate of mean level, U and B the amplitudes (semi-ranges) of the uninodal and binodal components, then $A=\frac{1}{2}(y_0+y_3)=y_2$, $U+B=\frac{1}{2}(y_3-y_2)$, $U-B=\sqrt{2}(y_1-A)=1{\cdot}414(y_1-A)$.

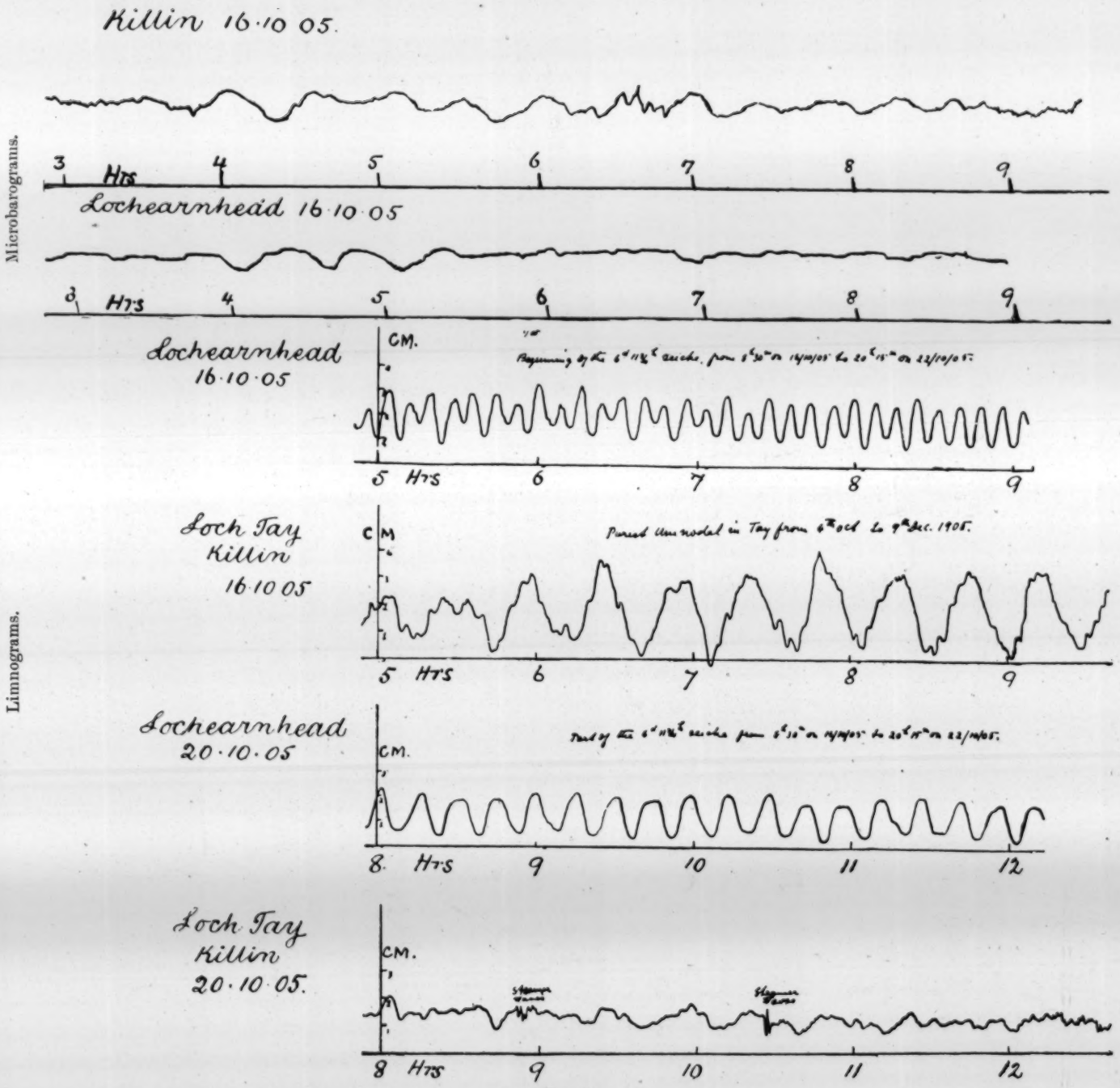

Killin 16·10·05.
Microbarograms.
3 Hrs 4 5 6 7 8 9
Lochearnhead 16·10·05
3 Hrs 4 5 6 7 8 9
Lochearnhead 16·10·05
CM.
5 Hrs 6 7 8 9
Loch Tay Killin 16·10·05
Limnograms.
CM
5 Hrs 6 7 8 9
Lochearnhead 20·10·05
CM.
8 Hrs 9 10 11 12
Loch Tay Killin 20·10·05.
CM.
8 Hrs 9 10 11 12

FIG. 2.

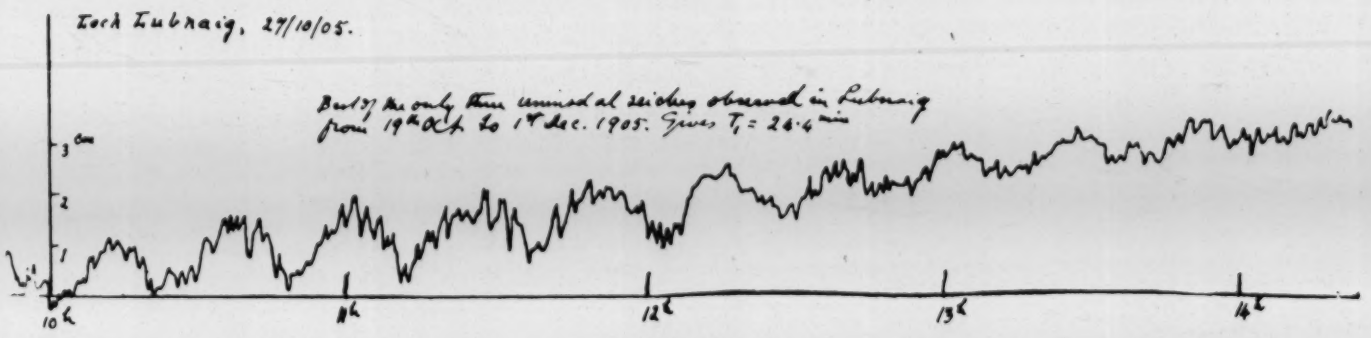

Loch Lubnaig, 27/10/05.
3 cm
2
1
10h
11h
12h
13h
14h

FIG. 3.

as the indications of the converted Sarasin limnograph were controlled by occasional observations with the much more delicate index limnograph.

For our disappointment in Tay and Lubnaig we find consolation in the beautiful seiche behaviour of Earn, which we regard as a small but elegant daughter of Geneva, the great mother of seiches.

## Origin of Seiches.

Forel and his followers, Du Boys, Von Cholnoky, and others, have discussed the causes of seiches; and recently Endrös, in his important memoir on the Chiemsee, has confirmed the conclusions of his predecessors, and added some fresh details of great interest. In what follows we shall not advance anything of great novelty; but there are two points of interest that may be worthy of the reader's notice. In the first place, the use of the Dines-Shaw microbarograph enabled us to follow continuously the minute variations of the atmospheric pressure with an ease and certainty hitherto unattainable.* Also, in an appendix to this memoir the mathematical theory of the effect of pressure disturbances of various kinds on an ideal lake, of form not very remote from Earn, has been worked out, so as to show that the usually assigned cause of seiches, viz. the minor local fluctuations of the barometric pressure, is in reality sufficient to cause the disturbances observed, and is not a negligible quantity on ordinary lakes, such as the tidal action of the moon can be shown to be.†

Regarding those causes of seiches which have never yet been proved to be other than accidental, it may be of interest to record the fact that during our observations, viz. on 21st September 1905, at $23^h\ 33^m$, we were favoured with what Dr C. Davison,‡ in a paper on the Ochil Earthquakes, calls a "principal earthquake." The estimated duration of the shock was 3·4 sec. Some of the members of my family who heard it, took it for the rumble of a train passing at an unusual hour on the opposite side of Loch Earn. The centre of disturbance seems to have been about 19 miles S. 39° E. of St Fillans; and the normal to Dr Davison's isoseismal 4 makes an angle of about 63° with the axis of Loch Earn.

At the moment the Waggon recorder was not working; but the converted Sarasin at the binode was running at high speed (158 mm. per hour) and giving a smooth trace. The circumstances were as favourable as could be conceived for showing any seiche disturbance due to the earthquake; but none can be identified. There is, of course, no reason to expect that the rapid oscillations of ordinary earthquakes could cause seiches. Still, negative evidence in special cases is not without value; because in exceptional cases, such as the Lisbon earthquake of 1755, seiches have been produced, and we do not as yet know the reason why.

* A separate account of the observations with the microbarographs has been published in the *Proceedings* of the Society, vol. xxviii., p. 437 (1908).

† Except in very large lakes, such as Erie. See Endrös, *Petermanns Geogr. Mittheilungen*, 1908, Heft ii., p. 16.

‡ *Quart. Jour. Geol. Soc.*, lxiii., p. 366 (1907).

Observers are now agreed that the development of seiches usually accompanies local disturbances of the barometric pressure whose duration if they are transitory, or period if they are periodic, does not differ greatly from the period of the seiche in question. Our observations on Earn fully bear out this conclusion. Disturbance on the microbarogram is always accompanied by disturbance on the limnogram, although the magnitudes do not always correspond. Sometimes a violent disturbance on the microbarogram is accompanied by a moderate or slight disturbance on the limnogram; and occasionally the disturbance on the limnogram is much greater than might at first sight be expected from the microbaric disturbance. The mathematical theory (and indeed common sense apart from recondite theory) indicates the reason for this. If an increase of pressure operates on one half of a symmetric parabolic lake during half the period of the uninodal seiche while the water in that half is falling, it will evidently work the whole time towards increasing the amplitude of the seiche. Also, if there were to be increase of pressure for half-periods alternately on the two sides of the uninode, always tending to drive the water in the direction in which it was going, it is obvious that a very small increase might end by producing a very large seiche. As a matter of fact, we do find occasionally a considerable rise of seiche when the microbarogram is comparatively smooth; but in such cases a closer examination usually shows a faint undulation with a period not very different from that of the seiche which is generated.

On the other hand, if we suppose our increase of pressure to act on one half of the parabolic lake during the whole period of the uninodal seiche, or if it is distributed equally on both sides of the uninode, it is easy to see that the final result in altering the range of the seiche will be nil, however long the increase of pressure may act.

Absence of microbaric disturbance is accompanied by absence of seiche disturbance; that is to say, either there is no seiche at all, or an existing seiche continues unaltered. Under these circumstances the limnograms from Earn are of great beauty. As an example, we may mention a record taken by the converted Sarasin near the binode from 23rd to 27th August. This shows a regular uninodal seiche with an average range of 6 to 7 millimetres, which continued for over 89 hours. During all that time the microbarogram shows only very slight disturbance—faint undulations, occasionally periodic. The range of the seiche is not absolutely constant, but sometimes rises and sometimes falls gradually, the minimum being, say, 4·5 mm. and the maximum 8 mm. (corresponding to 7·7 mm. and 13·6 mm. at St Fillans). There is nowhere any sudden change of phase.

Examination of the limnograms shows that seiches may be generated "suddenly," *i.e.* attain their full range in one or two oscillations, or may be generated "gradually," *i.e.* the full range may be attained only after a considerable number of oscillations.

Among the causes that might generate seiches suddenly we may consider the following:—

1. The sudden release of a static denivellation of the whole lake-surface, due to the progression of the general system of the atmospheric isobars.

2. Sudden release of a denivellation caused by the transport of water from one end of the lake to the other by a wind which has blown in one direction for a time and then fallen calm or reversed its direction.

3. A sudden denivellation in one part of the lake due to very rapid flooding.

4. A sudden denivellation due to a heavy fall of rain, snow, or hail over a part of the lake. This might be partly static, *i.e.* due merely to the gravitation of the precipitated water; or it might be partly dynamic, *i.e.* due to the impact of the precipitated water.

5. Sudden alteration of the atmospheric pressure, due to the passage over parts of the lake of a local atmospheric disturbance (squall), such as is indicated by a disturbance on the microbarogram.

6. The impacts of wind-gusts on the lake-surface.

Among causes that might be expected to generate seiches gradually may be mentioned:—

7. The action over portions of the lake-surface of small fluctuations of the barometric pressure which happen to synchronise more or less nearly with some of the seiche periods of the lake.

8. Action similar to last of fluctuation in the velocity and pressure of the wind, as shown in the anemogram.

1. *Effect of the Progression of the General System of the Isobars.*—In order to form an idea of the potency of cause 1, let us take an extreme case. The greatest gradient noticed on the weather charts for August and September 1905 was 2·5 mm. of mercury, *i.e.* 34 mm. of water, in about 30 sea miles. Taking the length of Earn as 6 miles, this would give a difference of pressure between the two ends of 6·8 mm. of water. At a distance of about 50 miles on the chart the gradient had fallen by about one-fifth. If we take an extreme supposition, viz. that the system of isobars travelled with a velocity of 30 (mile/hour) in the direction of maximum gradient, which we further assume to be in the axis of Loch Earn, then the decrease of pressure difference in an hour would be $6{\cdot}8 \times 3/25$. A variation of this kind (if we suppose the gradient uniform over Earn) can only generate the uninodal of Earn,* the period of which we may take roughly to be $15^{m}$. If now we suppose the time of action to be the most favourable, viz. $7\frac{1}{2}^{m}$, and the increase of the gradient to be uniform in time, then, by the result given in the Appendix on p. 513, the increment in the range of the uninodal seiche is

$$6{\cdot}8 \times 3/25 \times 16 = {\cdot}051 \text{ mm.}$$

An alteration of this amount would of course be invisible on our limnograms. It seems hopeless, therefore, to look for an explanation of ordinary seiches in the variations of the general system of isobars shown in the daily weather charts.

2. *Effect of Wind Denivellation.*—It is well established by the researches of Sir

* See Part V., p. 513.

JOHN MURRAY that a wind which has prevailed for some time causes transport of the water of a lake in the direction in which the wind is blowing; and the observations of VON CHOLNOKY on Lake Balaton show that in shallow lakes this wind denivellation may be considerable, and that its sudden release may give rise to seiches.

After a long and careful examination of our limnograms, we have arrived at the conclusion that this kind of denivellation is very small on Loch Earn under ordinary circumstances, and is rarely an effective cause of seiches. It is, however, not easy to judge of this matter. When the wind is light, the effect is very small, and cannot be separated from the denivellations due to precipitation and evaporation, and to variations in the barometric gradient. When the wind is high it is usually accompanied by considerable fluctuations of the barometric pressure, or by rainfall, or by both; and again the difficulty of separating the causes arises. That wind denivellation should be small on Earn is not surprising, for, looking at the ratio of its depth to its length, we must classify it as a deep lake; and in such lakes, as is now well known, the return undercurrent readily forms, and prevents the accumulation of wind denivellation.

It may be of interest to record one or two of the more striking cases which were examined.

On 18th August at $16^h\ 46^m$ the microbarograph showed a nearly uniform increase of 8·8 mm. (water) in the atmospheric pressure in about half an hour. At $17^h\ 5^m$ the wind had fallen dead calm, and so continued for about $25^m$. Then in $12^m$ to $13^m$ it rose to a mean velocity of 25 (mile/hour), with an extreme of 38. Thereafter a mean velocity of 18 to 20 was maintained for over three hours. The squall at $17^h\ 30^m$ was very violent. One of my boys was out in a boat on the lake, and saw a large solitary wave travel up from west to east. The water was calm in front, but very rough behind; and after the wave came the strong wind. He estimated the height of this wave at 2 feet; but, as he was badly scared by the difficulty experienced in navigating his boat, he most likely exaggerated.

The effect of this remarkable wind-squall on the limnogram is comparatively slight. There is a rise of 11 mm. or so, which took over two hours to develop. There is some increase, but not much, of the characteristic wind embroidery, and a considerable disturbance in the phases of the somewhat irregular UB-dicrote which had prevailed before the squall. But there is no very marked permanent increase in the general range of the seiche.

From $22^h$ on the 18th there is a great increase in the range of the seiche, till it reaches 79 mm. about $4^h\ 30^m$ on the 19th (see fig. 4)—the greatest range we observed on Earn. This increase was clearly due to the barometric disturbances indicated by the microbarograph, which at the moment of maximum range had a period of about $12^m$.

It is specially notable that the seiche was not further increased by the great increase of wind between $5^h$ and $7^h$. The maximum of wind follows the maximum of seiche in this case, as in several others that were closely examined. As the velocity

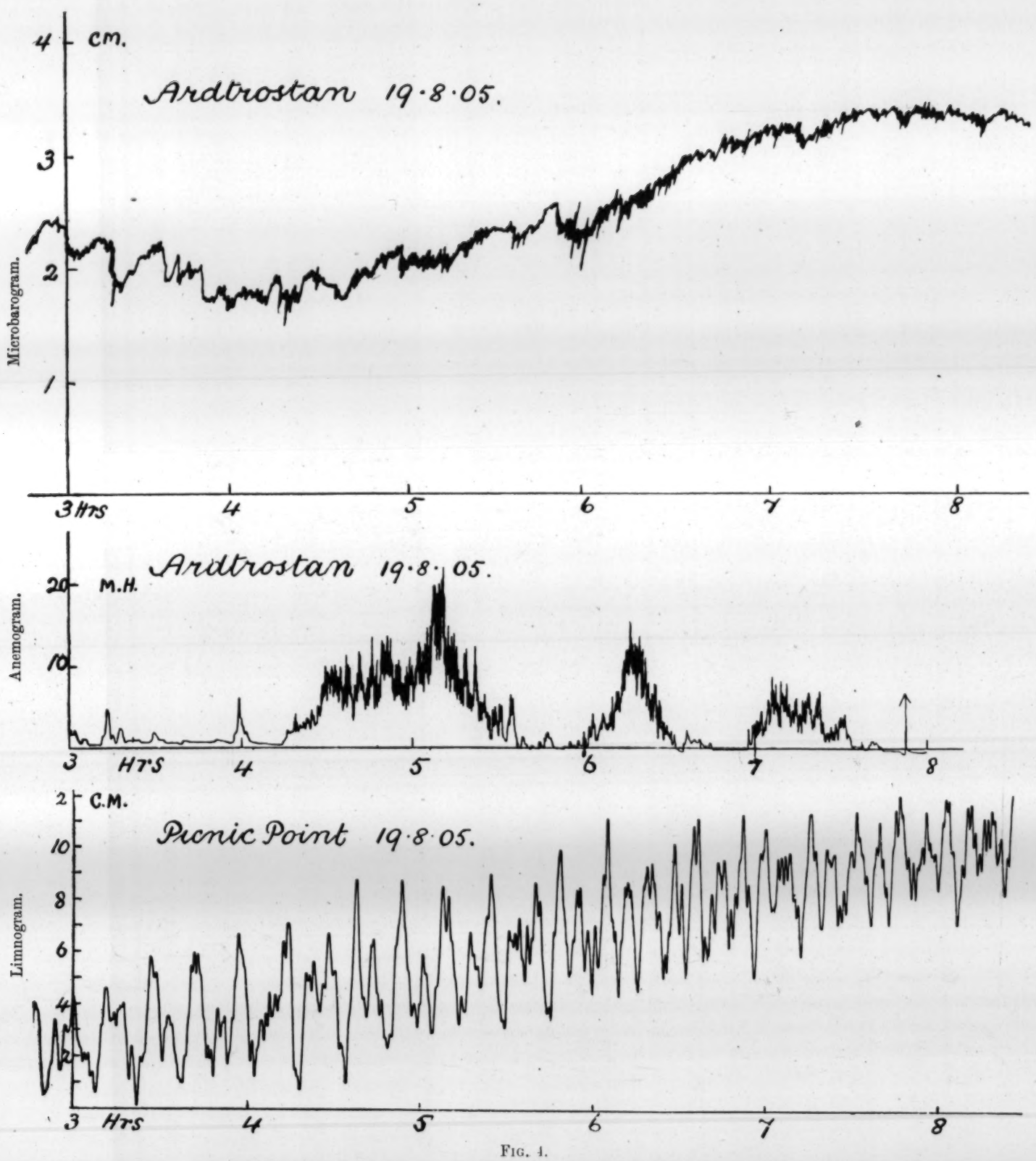
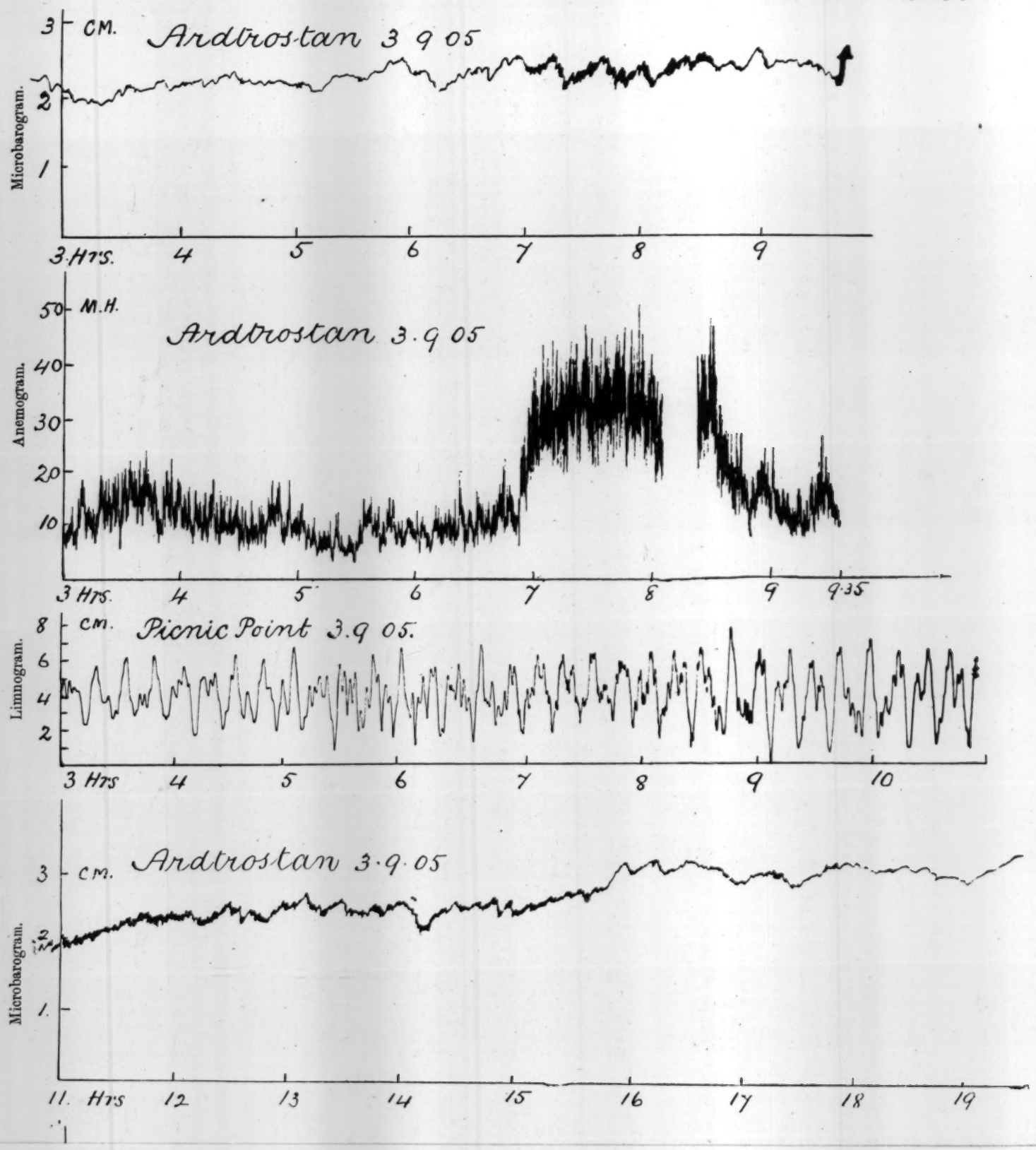



FIG. 4.

of the wind ranged from 15 to 35 (mile/hour), this can hardly have been due to the fact that the anemometer was nearer the leeward than the windward end of the lake.


Microbarogram.
3
2
1
CM.
Ardtrostan 3 9 05
3 Hrs.
4
5
6
7
8
9
Anemogram.
50
40
30
20
10
M.H.
Ardtrostan 3.9 05
3 Hrs.
4
5
6
7
8
9
9·35
Limnogram.
8
6
4
2
cm.
Picnic Point 3.9 05.
3 Hrs
4
5
6
7
8
9
10
Microbarogram.
3
2
1.
cm.
Ardtrostan 3·9·05
11. Hrs
12
13
14
15
16
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19

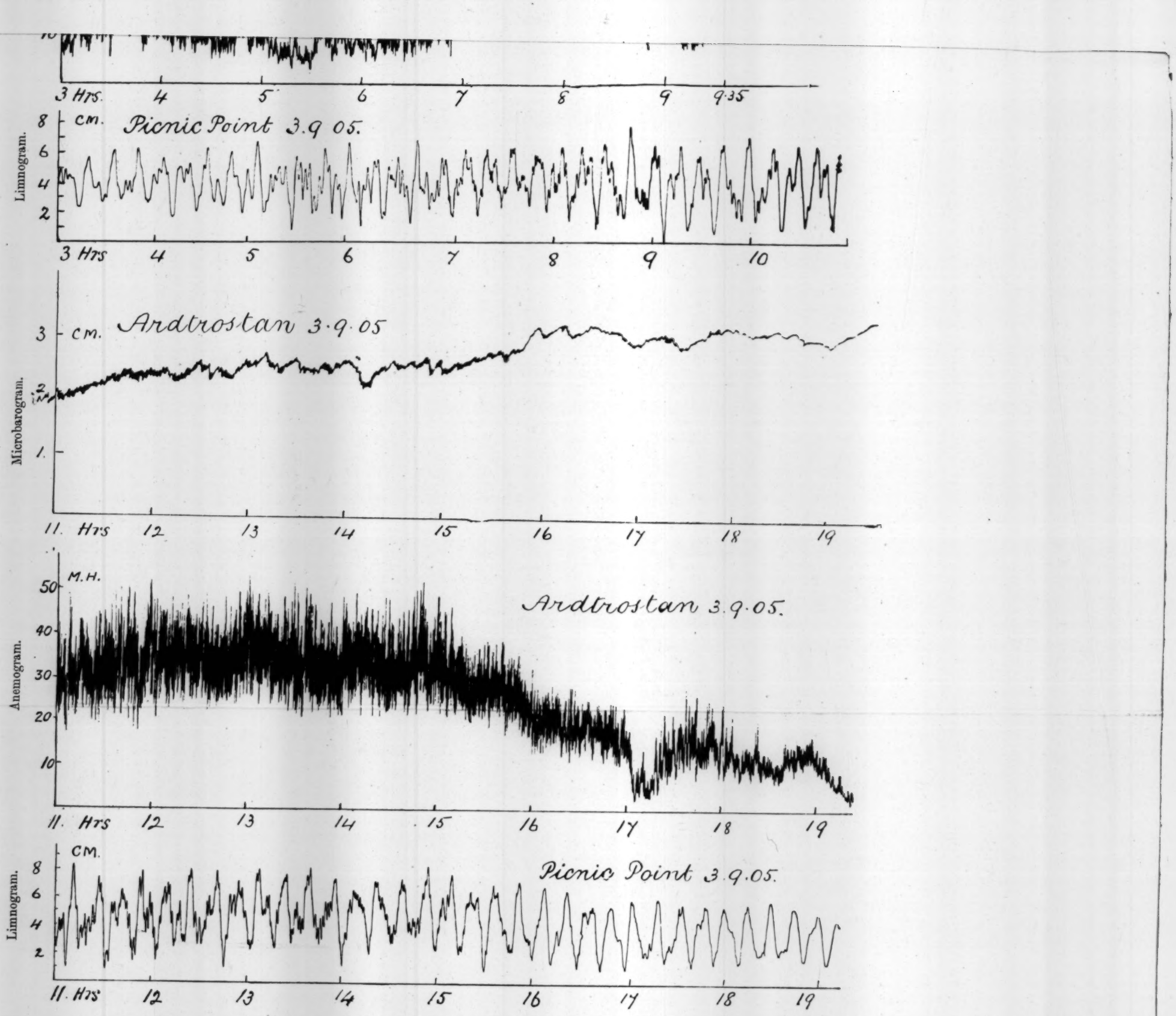

3 Hrs. 4 5 6 7 8 9 9·35
Limnogram.
8 cm. Picnic Point 3.9 05.
6
4
2
3 Hrs 4 5 6 7 8 9 10
Microbarogram.
3 cm. Ardtrostan 3·9·05
2
1.
11. Hrs 12 13 14 15 16 17 18 19
Anemogram.
M.H.
50
40
30
20
10
Ardtrostan 3.9.05.
11. Hrs 12 13 14 15 16 17 18 19
Limnogram.
CM.
8
6
4
2
Picnic Point 3.9.05.
11. Hrs 12 13 14 15 16 17 18 19

FIG. 5.

The seiche of 3rd September 1905 (fig. 5) is interesting because it was accompanied by the strongest gale experienced during the two months of observation.

For some hours before midnight the wind had been very light, and at $2^h$ it was practically calm. About $2^h\ 37^m$ the wind began to rise; and in an hour it had reached a mean velocity of about 15 (mile/hour). The velocity fluctuated between 6 and 15 till $7^h$, when a very sudden rise began. By $7^h\ 30^m$ the average velocity had risen to 35, with extremes of 45 to 50. About $8^h\ 30^m$ there was a sudden drop to about 25, then a more gradual drop to 10 at $9^h\ 20^m$. After that the gale rose again to a mean velocity of 35 to 40, with extremes occasionally reaching 53. After lasting four hours, the gale began to abate about $15^h$; and then fell more or less uniformly to calm about $20^h$, there being two rather sudden lulls at $17^h$ and $19^h\ 20^m$.

Throughout the whole of this time the microbarogram is much disturbed. During the strongest parts of the gale it shows the characteristic wind blurring, and throughout there are fluctuations of various periods: *e.g.* 7·2′ at $2^h$, 5·6′ at $4^h\ 30^m$, 13·6′ at $8^h\ 30^m$, 17′ at $16^h$.

Till about midnight there had been a fairly regular UB-seiche with a small trinodal component, the total range of the whole being about 31 mm. Soon after midnight, that is, more than $2\frac{1}{2}$ hours before the wind began to rise, the limnogram begins to show serious disturbance. This disturbance becomes strongly marked at $5^h$, when the total range of the seiche reaches 60 mm.; and there is a strong development of seiches of higher nodality, in particular of one having a period of about $2{\cdot}9^m$.

At $7^h$, when the wind suddenly rises into a gale, there is no very marked change in the seiche. But between $8^h\ 30^m$ and $9^h$ there is an increase in the total range from 56 mm. to 78 mm., due no doubt to the simultaneous microbaric disturbance, which has a period of about $13{\cdot}6^m$. After this the seiche tends to settle down into a UB-dicrote, strongly embroidered with higher components while the gale lasts. It is worthy of note that at $14^h$, *i.e.* 7 hours after the gale commenced, the mean level of the lake at Picnic Point has only risen about 6 mm. About $16^h$ there is a decrease in the total range of the seiche from 64 mm. to 51 mm. This may be due partly to the drop in the wind, but much more probably to the simultaneous microbaric disturbance, which has a period of about $17^m$, and would strongly affect the uninodal component of the seiche.

The range of the disturbance on the microbarogram was a little under 2 mm.; and our data from the triangle of microbarographs showed that it travelled along the lake with a velocity of 53 miles an hour. For rough purposes and for convenient calculation we may take 48 instead of 53; and suppose the period of the pressure disturbance and also of the uninodal period to be $15^m$, and the circumstances as to phase to be the most favourable possible. The formula (57) of the mathematical Appendix to this memoir then gives for the addition to the amplitude of the uninodal in $15^m$ $\partial k_1 = \frac{3}{4}\partial p = 3$ mm. The effect after two undulations will therefore be 6 mm., that is, an alteration of 12 mm. in the range of the seiche, which, as it happens, is within a millimetre of the value observed.

3. *Case in which a Seiche was probably caused by a Flood.*—Fig. 6 shows the limnogram, taken near the binode, of a seiche disturbance beginning at $16^h\ 9{\cdot}6^m$ on 4th August

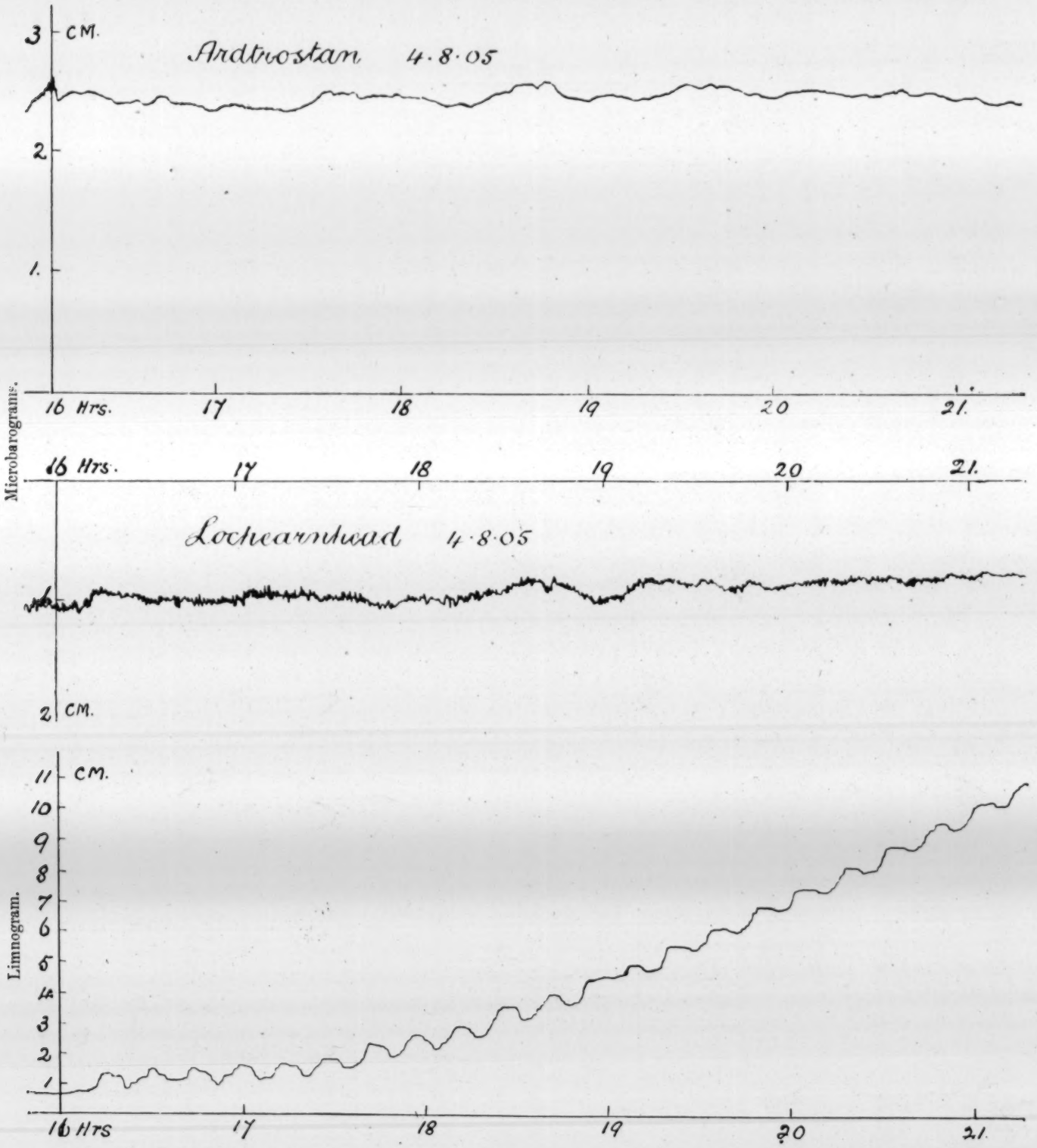



FIG. 6.

1905. The upward slope is due to a sudden rise in the lake caused by heavy rain. On the 3rd there had been ·96 in. of rain, and on the 4th 2·03 in., the greatest rainfall

observed during August and September. The limnograms taken at the uninode and Picnic Point are similar, except that the former shows merely a feeble binodal seiche, while the latter has a well-marked trinodal superposed on the uninodal seiche.

The wind on the 4th was light and easterly ; but a well-marked barometric depression, travelling with a velocity of about 18 (mile/hour), passed in a direction towards N. 15° E., probably a little to the west of Loch Earn, the centre being nearest about $0^h\ 52^m$ on the 5th.

The microbarograph at Ardtrostan shows a somewhat gradual drop of 2 mm., followed by a sharp rise of 4 mm. between $15^h\ 44^m$ and $16^h\ 3^m$.

It does not appear that either the passage of the main depression or the minor fluctuation attending it could have caused the sudden initial rise shown on the limnogram at $16^h\ 9{\cdot}6^m$. Both of these causes would indeed have worked, if at all, in the opposite direction.

We are therefore driven to the probable conclusion that the uninodal seiche was caused by the flood. A glance at the map shows that the area—Glen Beich, Glen Ogle, Glen Droma, Glen Ample, and Glen Voirlich—which drains into the western half of Loch Earn, much exceeds that—Glen Tarken, Allt an Fionn, and Finglen—which drains into the eastern half. It appears from the limnogram that for some time after the flood commenced the level of the whole lake was rising at the rate of ·32 mm. per minute. In half the period of the uninodal seiche this would give us a rise of 2·3 mm. If we suppose this flood at the very beginning to be thrown only on the western half of the lake, we have a disturbance equivalent to an increase of atmospheric pressure of 4·6 mm. of water. Acting during half the uninodal period, this, according to the calculation given in Part V., p. 503, would produce uninodal and trinodal seiches having extreme amplitudes of 6·8 mm. and 2·8 mm. If the first incidence of the flood were concentrated on, say, the western quarter of the lake-surface, the resultant seiche would of course be still greater. The rise shown at the binode was actually about 5·5 mm., which corresponds to an extreme amplitude for the uninodal seiche of 9·4 mm. It is therefore quite possible that the seiche may have been wholly due to the sudden flood on the western half of Loch Earn, and there appears to be no other way of accounting for it.

4. *Effect of Rainfall.*—In order to obtain an idea of the effect of heavy rainfall in causing a seiche, let us suppose a cloudburst to fall on the eastern half of Loch Earn (idealised into a symmetric parabolic lake). If $\sigma$ denote the rainfall in centimetres per second, $v$ the velocity of the rain-drops as they reach the surface of the lake, $p$ the pressure at time $t$ after the shower begins, then we have

$$\begin{aligned} p &= \sigma(v+gt) \quad \text{(dyne/cm.}^2\text{)} \\ &= \sigma v/g + \sigma t \quad \text{(gm./cm.}^2\text{)} ; \end{aligned}$$

or, if we measure the pressure in millimetres of water,

$$\begin{aligned} p &= 10\sigma v/g + 10\sigma t \\ &= q + rt, \quad \text{say.} \end{aligned}$$

Let us suppose that the shower begins when the uninodal seiche culminates, and that it lasts for half the uninodal period. Then, if $\partial k_1$ denote the alteration in the amplitude of the uninodal seiche at the end of the lake, we get, from formula (46) of Part V.,

$$\partial k_1 = \tfrac{3}{2}q + \tfrac{3}{4}r\mathrm{T}_1,$$

where $\frac{3}{2}q$ is due to the impact, and $\frac{3}{4}r\mathrm{T}_1$ to the static effect of the precipitated water.

To take an extreme case,* let us put $\sigma = \cdot 3/60 = \cdot 1/30$, $v = 700$. Then, taking $\mathrm{T}_1 = 15 \times 60$ as a round number, we get $q = \cdot 024$, $r = 1/30$. Hence

$$\partial k_1 = \cdot 036 + 22 \cdot 5 = 23 \text{ mm., say.}$$

The result would therefore be a seiche having a range of 46 mm. It will be noticed that the effect arising from the impact, viz. ·036, is negligible.

The conclusion thus arrived at bears out the inference of Endrös † regarding the effect of a rainfall of 7 mm. during $20^{\mathrm{m}}$ upon the $43^{\mathrm{m}}$ seiche of the Chiemsee. Such a fall on one half of a parabolic lake having a $40^{\mathrm{m}}$ period would generate a uninodal seiche having a range of 10·5 mm.

We have little doubt that in some of the cases, to be cited presently, the precipitation played an important part; but the observations of Shaw and Dines on the effect of passing rain-clouds in raising the barometric pressure tend to place difficulties in the way of separating the effect of precipitation from the barometric pressure proper. It would appear that the pressure to which the lake reacts so delicately is equal to the pressure before the rain has fallen, that is, while it is still in the cloud in the form of vapour; but the matter requires and deserves further investigation.

5. *Effect of Squalls.*—On 11th August, $8^{\mathrm{h}}$ to $9^{\mathrm{h}}$, a prolonged depression on the microbarogram is associated with a prolonged elevation on the limnogram. The release of this denivellation caused a considerable uninodal seiche (see fig. 7).

The embroidery on the two limnograms is interesting. It has the same period, $\mathrm{T} = 1 \cdot 15^{\mathrm{m}}$, at the binode and at the Picnic Point.

The limnogram taken at the binode on 21st August between $11^{\mathrm{h}}$ and $17^{\mathrm{h}}$ gives a good illustration of the effect of the passage of well-marked disturbances, whose whole duration (including a positive and a negative phase) was not very different from the period of the uninodal seiche. The binodal limnogram in fig. 8 is a photograph from a very rough tracing which had to be made, because at the moment the Sarasin pen was out of order, and was replaced by a pencil which gave only a very faint trace.

It will be observed that there are two well-marked increases of range, one about $12^{\mathrm{h}}\ 15^{\mathrm{m}}$, the other about $14^{\mathrm{h}}\ 30^{\mathrm{m}}$. These are connected with two sharp V-shaped disturbances on the microbarograms, the first of which is preceded by a couple of undulations whose period is not very different from $15^{\mathrm{m}}$.

The velocities of propagation of the two disturbances in the direction of the axis of

* See Hann, *Lehrbuch der Meteorologie* (1906), pp. 270, 275.

† *Seeschwankungen beobachtet am Chiemsee* (1903), p. 103.

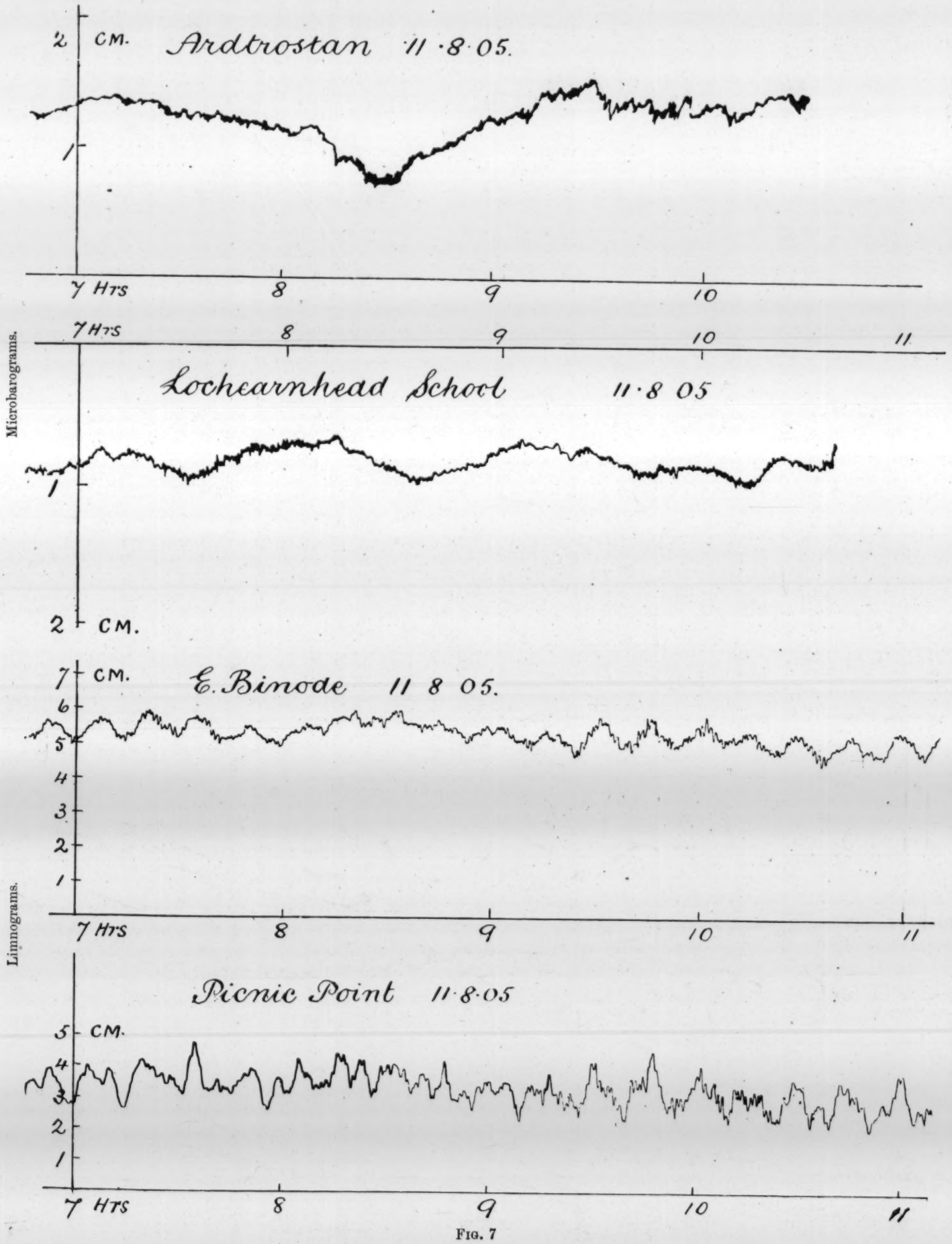

Ardtrostan 11·8·05.
2 CM.
1
7 Hrs
8
9
10
Lochearnhead School 11·8 05
7 Hrs
8
9
10
11
Microbarograms.
1
2 CM.
E. Binode 11 8 05.
7 CM.
6
5
4
3
2
1
7 Hrs
8
9
10
11
Limnograms.
Picnic Point 11·8·05
5 CM.
4
3
2
1
7 Hrs
8
9
10
11

FIG. 7

the lake were about 28 and 22 (mile/hour) respectively. To obtain some idea of the effectiveness of such disturbances, we may take this velocity to be $v$, and such that $v\mathrm{T}_1 = 2a$, where $\mathrm{T}_1$ is the uninodal period, and $2a$ the length of Earn. If we denote the pressure disturbance by

$$f(w, t) = \tfrac{1}{2}a \left\{ 1 - \cos \frac{n_1}{v}(vt - a(1+w)) \right\},$$

where $a = 8$ mm., say, and $f(w, t) = 0$ when $vt - a(1+w) > \text{or} < 2\pi$, then formula (46) of Part V. gives

$$4\partial k_1/3a = \int_{-1}^{+1} dw\, w \int_{a(1+w)/v}^{\mathrm{T}_1} dt\, n_1 \sin n_1 t \left\{ 1 - \cos \frac{n_1}{v}(vt - a(1+w)) \right\}$$
$$= -\cos 2\theta + \frac{5 \sin 2\theta}{2\theta} - \frac{2(1 - \cos 2\theta)}{\theta^2} + \frac{\pi(1 + \cos 2\theta)}{\theta} - \frac{\pi \sin 2\theta}{\theta^2},$$

where $\partial k_1$ is the increment of the amplitude of the uninodal seiche at the end of the lake,* and $\theta = 2\pi a/v\mathrm{T}_1$.

In the case supposed $\theta = \pi$, and we get

$$\partial k_1 = 3a/4 = 6 \text{ mm.}$$

Owing to the strong embroidery on the binodal limnogram, it is very difficult to estimate the actual increment of the seiche amplitude at either of the two dis-

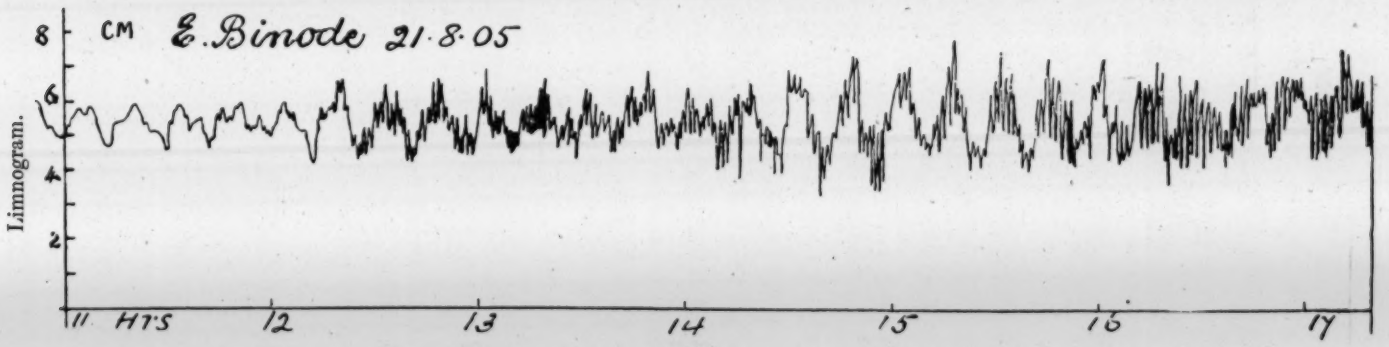



FIG. 8.

continuities; but it is clear that the results of calculation and observation are of the same order of magnitude.

It is interesting to note that the very strong short-period embroidery that blurs the binodal limnogram was almost totally absent on the limnogram taken at Picnic Point. During the day the wind had been variable in direction from south-east to south-west, gusty but never very high. The surface waves on the lake were not high during any part of the day; they came from the east in the morning, and from the west in the evening.

On the 7th of September, about $8^h\ 30^m$, occurred the greatest barometric fluctuation of short duration which we observed.† The extreme range was 19·3 mm. (Aq.), the

* *I.e.* 1·7 times the amplitude at the binodal limnograph.

† For further details, see my paper, *Proc. R.S.E.*, vol. xxviii., p. 457.

total duration about half an hour. It came from E. 56° N. with a velocity of propagation of 19 (mile/hour), the velocity along the lake being about 30.

As will be seen from fig. 9, the effect was to increase the total range of the seiche from about 18 mm. to 50 mm., and to generate a strong BT-dicrote. It is worthy of remark that the rise in the wind follows about an hour after the barometric disturbance. To the spiky anemogram which then follows corresponds a strongly embroidered seiche,

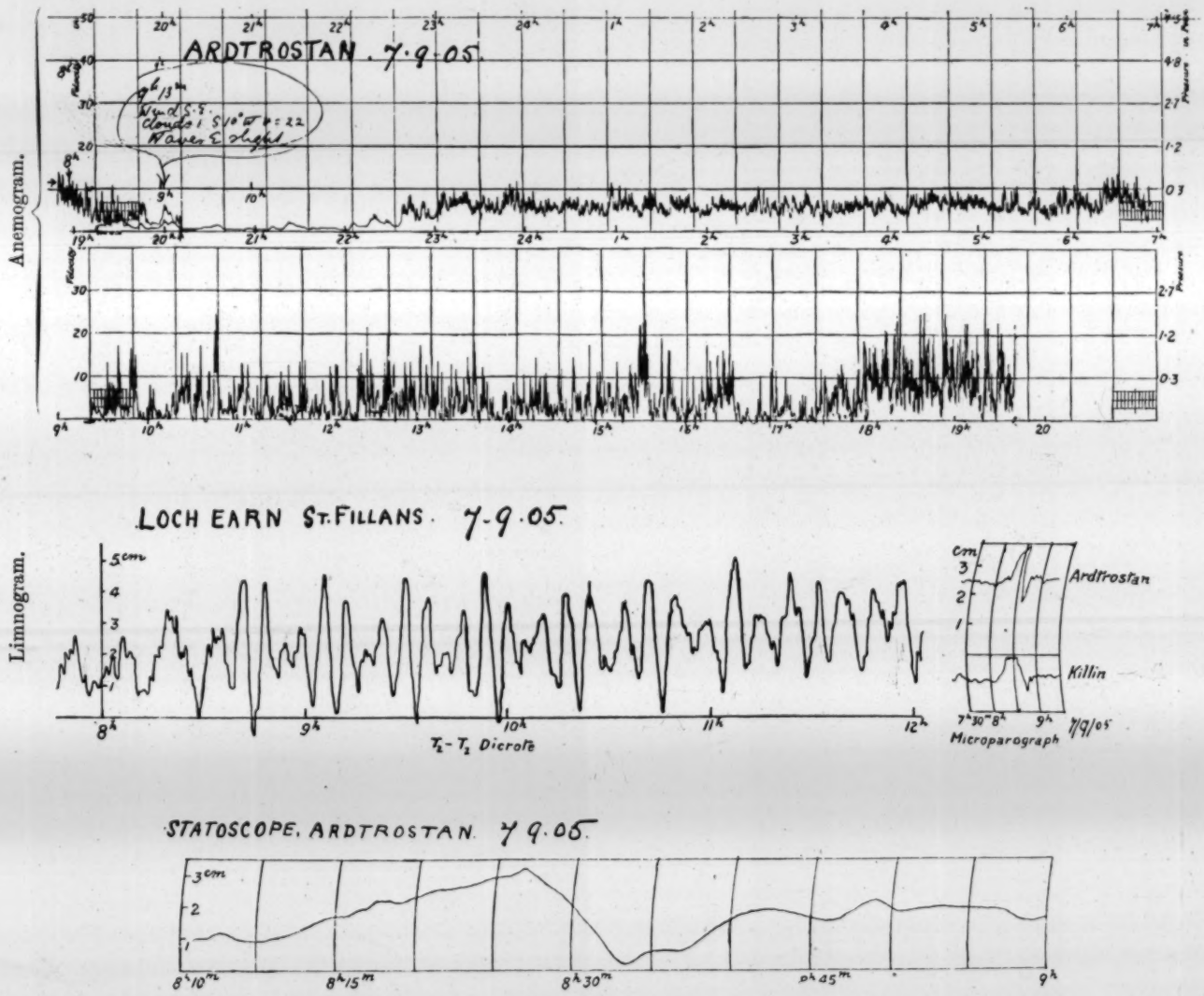
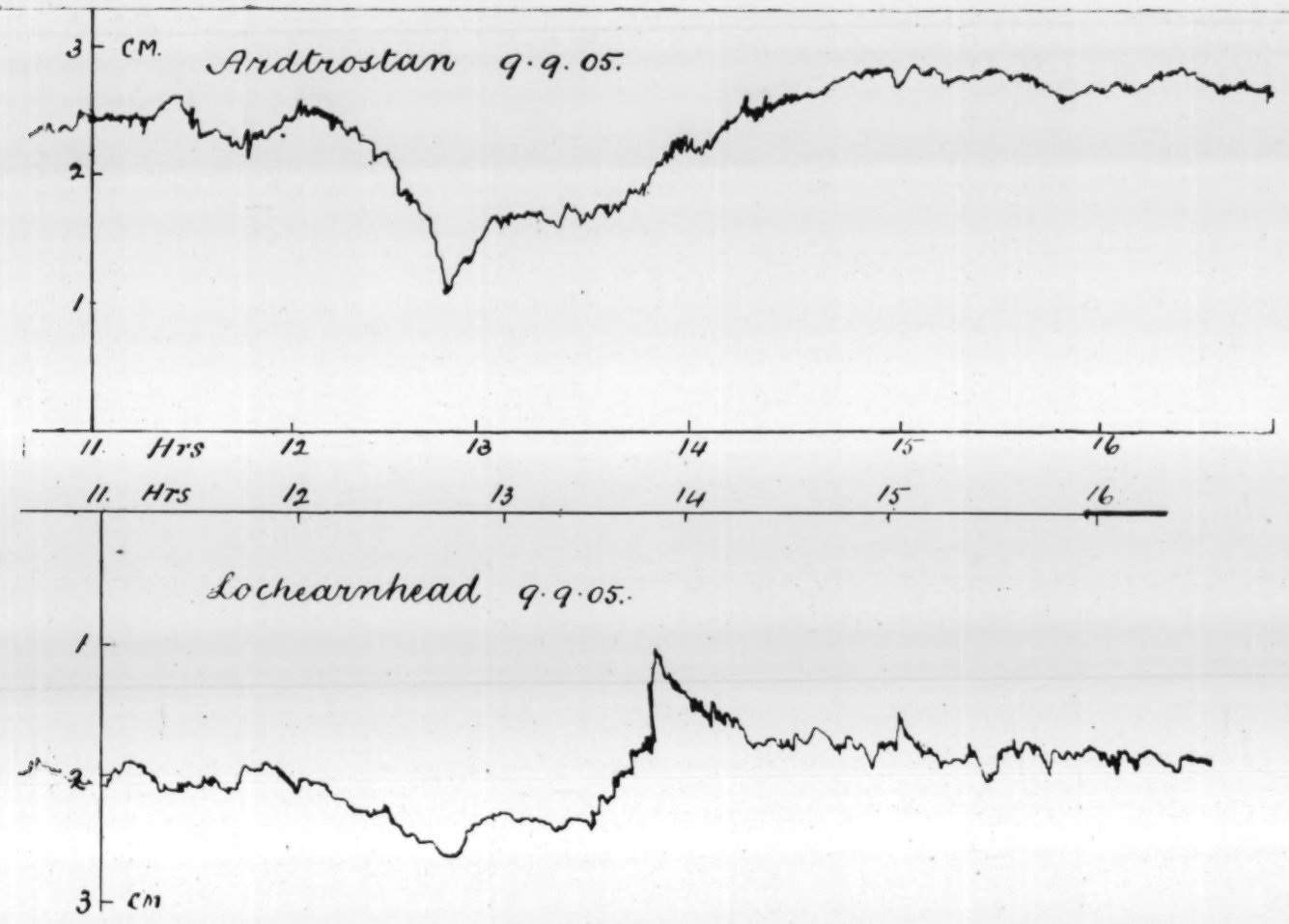



FIG. 9.

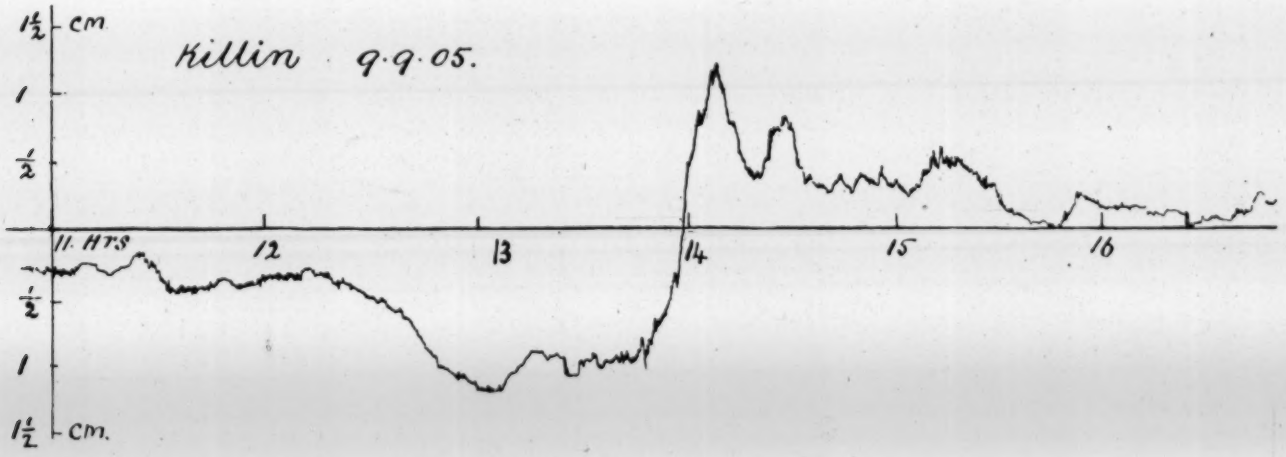
which shows no increase in maximum range. I have tried, but unsuccessfully, to find a period in the anemogram corresponding to that of the seiche-embroidery, viz. $T = 1{\cdot}5^m$ to $1{\cdot}6^m$.

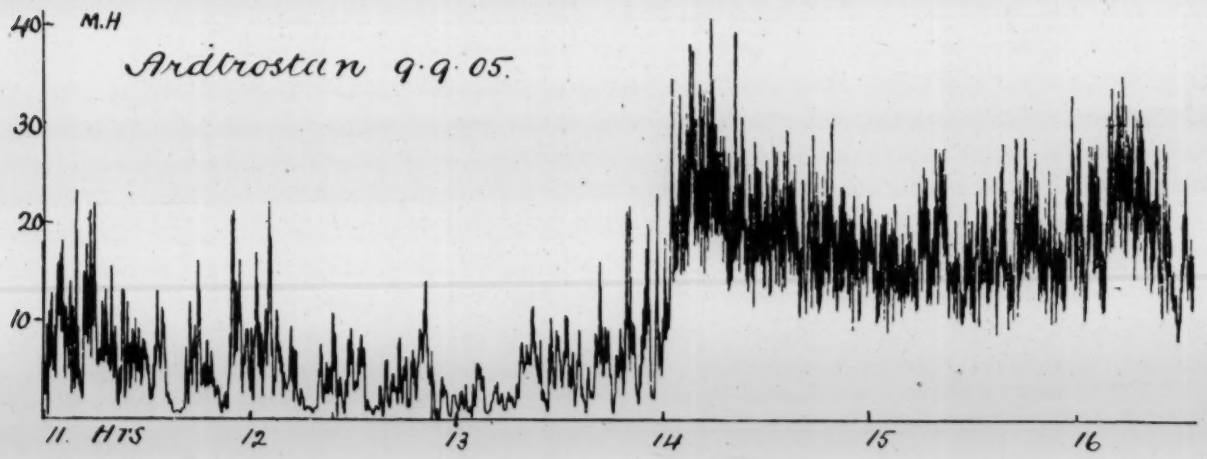
On 8th September, between $16^h$ and $17^h$, a well-marked barometric disturbance, having a range of 3 mm. to 4 mm. (Aq.), caused a change of phase in the previously existing UB-seiche, and also a considerable increase of range. This UB then persisted for nearly $24^h$, until about $13^h\ 15^m$ on the 9th September its configuration was utterly destroyed by the great barometric disturbance shown in fig. 10. This disturbance

Microbarograms.




Anemogram.




Limnogram.

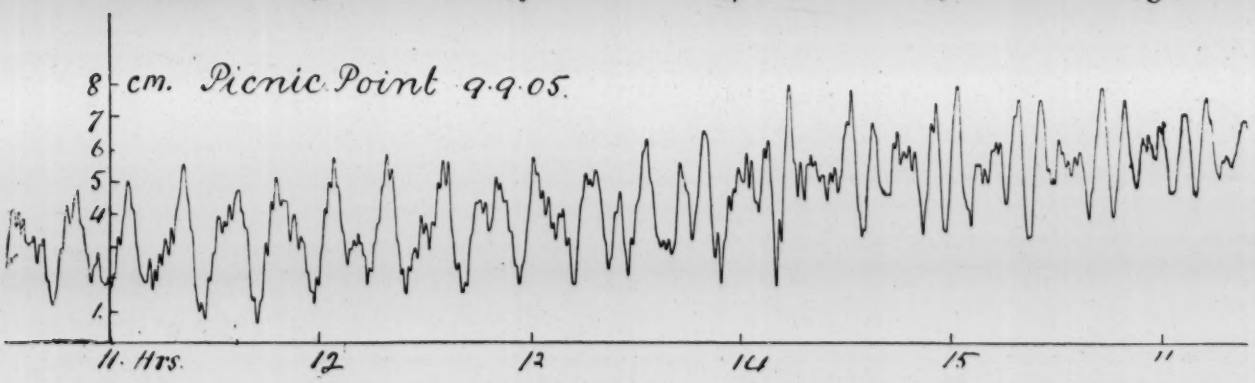



FIG. 10.

lasted nearly two hours, and caused a maximum depression of 14 mm. (Aq.); it came from W. 62° S. to W. 67° S., and travelled with a velocity of 17 to 22 (mile/hour), *i.e.* with a velocity of 33 to 51 along the lake. The sections of the disturbance at Killin and Lochearnhead on the one hand and at Ardtrostan on the other were very different. The minimum was rounded and pretty flat at the two former places, but cuspidal at the latter. Again, at Killin and Lochearnhead the minimum was followed by a sharp-pointed maximum, with an almost perpendicular rise; while at Ardtrostan the recovery after the minimum is very gradual, and there is only a little wart corresponding to the peaks at the other two stations.

It is interesting to notice that the minimum of the disturbance, although it destroys the configuration of the UB, and generates one of the best-marked BT-dicrotes that we observed, yet produces no great change in the total range of the seiche. It does produce a small rise of level at Picnic Point of 7 mm. to 11 mm. This is confirmed by the limnogram taken at the binode, where at that time the Sarasin was running at high speed (160 mm. per hour). This shows a rise of level of 5 mm., and a diminution in the range of the uninodal seiche of about 8 mm.

At $14^h\ 13^m$ there is a sudden rise of level of about 14 mm., evidently due to the intense action of the maximum of pressure developed towards the western end of the lake, which there is nothing to counterbalance on the eastern part. It is after this point that the new BT configuration becomes conspicuous. As will be seen from the anemogram, the barometric and seiche disturbances at $14^h$ were associated with a very sudden rise in the average wind velocity from 5 to 25 (mile/hour).

*The Glen Ogle Storm.*—It seems unnecessary further to multiply instances of the connection between abrupt barometric and seiche disturbances. I shall therefore conclude this part of my report by describing one of the most remarkable observations we made on Loch Earn.

On the 23rd August, after a dead calm during the night and heavy rain in the early morning, at $8^h\ 20^m$ there was a light breeze, W., 5 (mile/hour). There was low cumulus on the hills to E. and N.E.; but there was bright sunshine, and the clouds (3) in general were high. The main drift was from S.E.; but there was a mackerel formation apparently moving in a different direction; also a mare's-tail showed to S.W.

The waves were running from W.—a slight swell diversified by oil bands, which were seen at intervals throughout the day.

From $8^h\ 20^m$ to $12^h\ 30^m$ the wind was light, fluctuating with a rough period of $1^h$. At $12^h\ 30^m$ there was a sudden gust of 15 (mile/hour). After that the wind rose somewhat, and fluctuated for about 5 hours between 0 and 13 (mile/hour) mean velocity. It was unusually gusty, and at $14^h\ 5^m$ an extreme velocity of 25 (mile/hour) was registered. At this moment a black rain-cloud came down Glen Ogle, and reached over the western part of the lake as far as Ardvoirlich, where it stopped.

At $14^h\ 50^m$ there came on a sudden rain-shower, the wind being then W. by S. After this there was rain at intervals till $20^h\ 18^m$, an especially heavy shower at $17^h\ 20^m$.

At $20^h\ 18^m$ the wind was W.S.W. and variable.

At $14^h\ 7^m$ a microbaric disturbance passed Ardtrostan, travelling with a velocity of 15 (mile/hour) from W. 60° N. (36 along the lake).

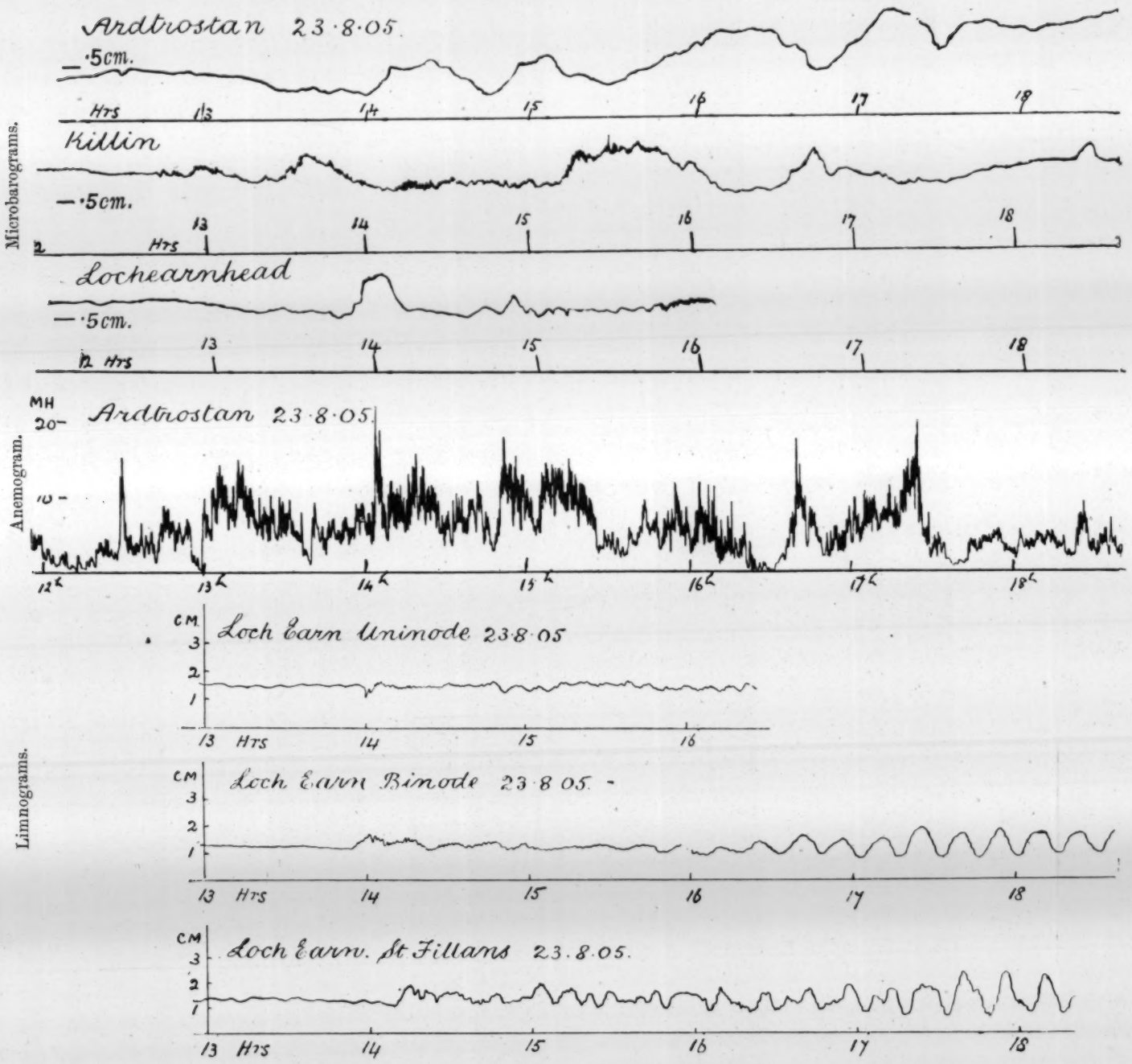



FIG. 11.

One of the Lake Survey staff was looking at the uninodal limnograph, and saw it record the sharp depression shown in fig. 11, just as the squall came up. For some time before, the limnographs at the uninode, binode, and Picnic Point had been drawing almost straight lines. The seiche weather had, in fact, been the calmest known in our two months of observation.

The maximum depression (4 mm.) at the uninode and the maximum elevation (5 mm.) at the binode were nearly simultaneous, the latter apparently following about $1\frac{1}{2}^m$ after the former. Unfortunately, owing to the irregularity of the clock at the uninode, certainty on this point is not attainable.

It seems clear that an abrupt elevation of the surface travelled along the eastern part of the lake. The first rise began at the binode at $13^h\ 55{\cdot}31^m$; and at the Picnic Point at $14^h\ 5{\cdot}24^m$, that is, $9{\cdot}93^m$ later. The first maximum (5 mm.) is seen at the binode at $14^h\ 1{\cdot}05^m$; and at Picnic Point at $14^h\ 10{\cdot}57^m$, that is, $9{\cdot}52^m$ later. The velocity of propagation of the first rise would thus be 6·0 (mile/hour), and of the first maximum 6·3 (mile/hour); and it is interesting to notice that by the time the wave has reached Picnic Point a shallow minimum has developed in front of the maximum. If the wave had travelled as a solitary long wave, it would have taken only about $7^m$ to travel from the binode to Picnic Point.

After the wave reached St Fillans it seems to have been reflected backwards and forwards between the ends of the lake, at first with a good deal of irregularity; but gradually it developed the characteristics of a regular dicrote seiche. There are two points (easily seen on the binodal limnogram), viz. $16^h$ and $17^h\ 20^m$, where the range of the seiche was suddenly increased, evidently by barometric disturbances which occurred at these times. The increase at $17^h\ 20^m$ may have been partly due to the heavy shower.

At $17^h\ 20^m$ on the 23rd the dicrote is fully developed ($2U = 11{\cdot}5$, $2B = 7{\cdot}0$). It retains its character, with gradually decreasing range, until a little before $24^h$ on the 24th. About that time the microbarograph at Killin shows disturbances with periods $T = 10^m$, $T = 15{\cdot}6^m$; and there is an alteration of the UB from $2U = 3{\cdot}7$ mm., $2B = 1{\cdot}7$ mm. to $2U = 11{\cdot}4$ mm., $2B = 1{\cdot}0$ mm. The dicrote then remains steady until $22^h$ on the 25th, when it undergoes a sudden disturbance, which rapidly destroys its configuration. This sudden disturbance and the almost total destruction of the seiche about 5 hours later are difficult to explain by the meteorological conditions, unless they were due to variations of the wind.

6. *Effect of the Impact of Wind-Gusts.*—Inasmuch as a wind velocity of 10 (mile/hour) is calculated to produce a pressure of about 1·5 mm. (Aq.) by direct impact on a small area, it is reasonable to expect that the impact of wind-gusts, especially in the case of lakes enclosed by high hills, may at times cause seiches. There are, however, various difficulties in obtaining data on the subject. It is difficult to determine the angle of impact of the wind-blasts. Then it is uncertain whether the wind ever falls at the same angle and at the same time over large parts of the surface of a lake. The appearance of the lake-surface on windy days very often suggests the contrary. What we frequently see are patches of wind disturbance progressing over the lake-surface with varying velocities.

Then again it is difficult to separate the effect of wind impact from the disturbances of the ordinary barometric pressure which always accompany high winds.

It has not been possible to deduce any definite results from our observations under the present head.

7. *Effect of Periodic Fluctuations of the Atmospheric Pressure.*—Our observations afford many examples of this cause of seiches. It must, however, be understood that strictly periodic fluctuations of the barometric pressure of short period rarely if ever occur. We often find, however, fluctuations extending over an hour or two in which

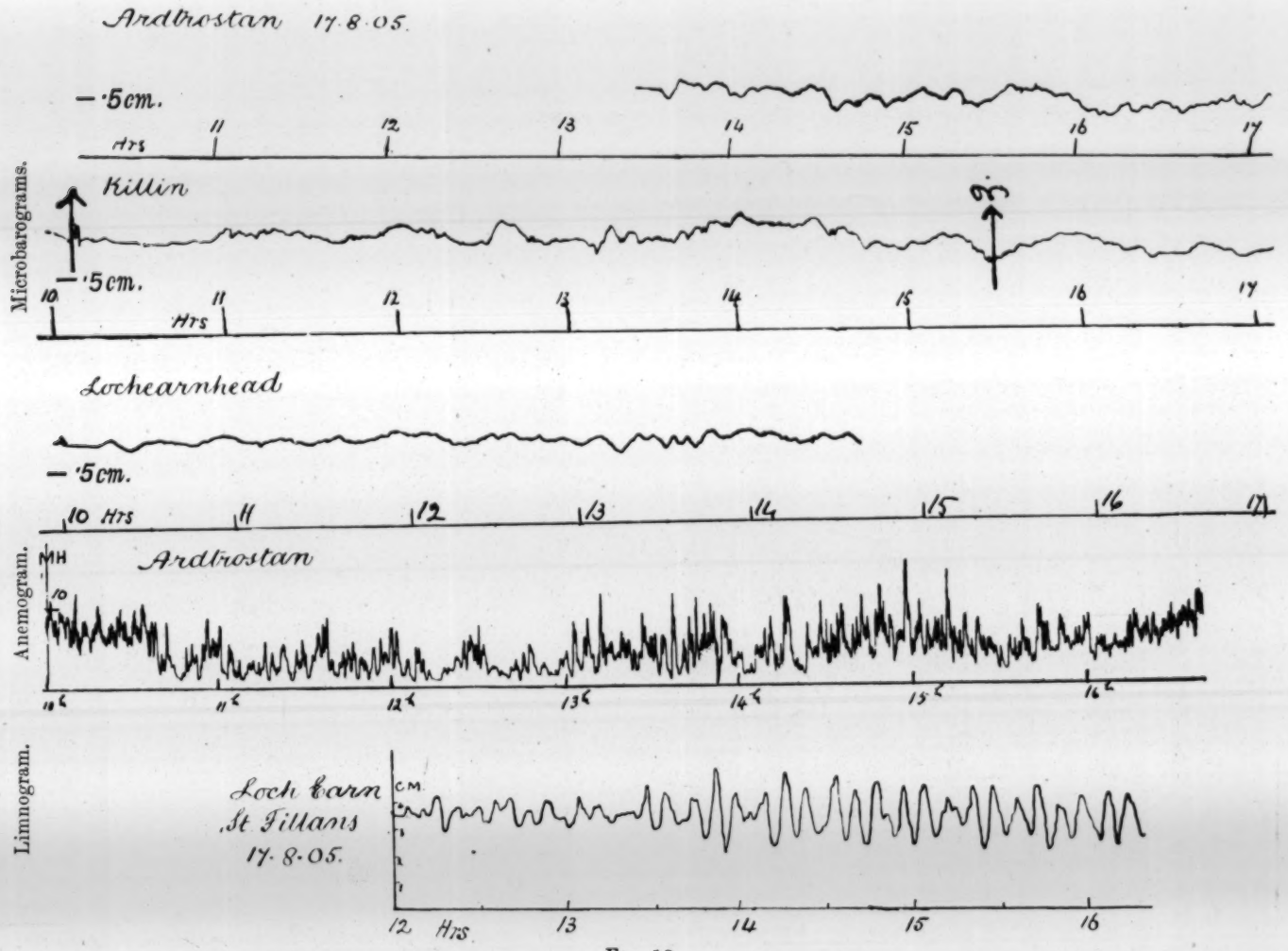



FIG. 12.

the undulations are approximately of equal length; and still oftener we find two or three consecutive undulations of approximately the same length. Such fluctuations we shall describe in what follows as periodic; and by the "period" is meant the average of the intervals between the passage of corresponding phases (say maxima) of two successive undulations at the same point.

It follows from theory, and is confirmed by observation, that a periodic disturbing cause is most effective when its period is not very different from that of the seiche in question. In practice, however, the disturbing effect is considerable even if there is considerable divergence between the two periods. It should also be noticed that, even theoretically, if we consider only one or a limited number of oscillations, and neglect

the viscosity, the maximum effect does not correspond to exact equality of the two periods.*

In what precedes we have already given some examples of the effect of a periodic disturbing agency; we shall now add a few more.

17*th August*.—Between 13$^h$ and 14$^h$ (see fig. 12) a strong binodal seiche with a trinodal component is worked up by resonance with the pressure disturbance shown on the

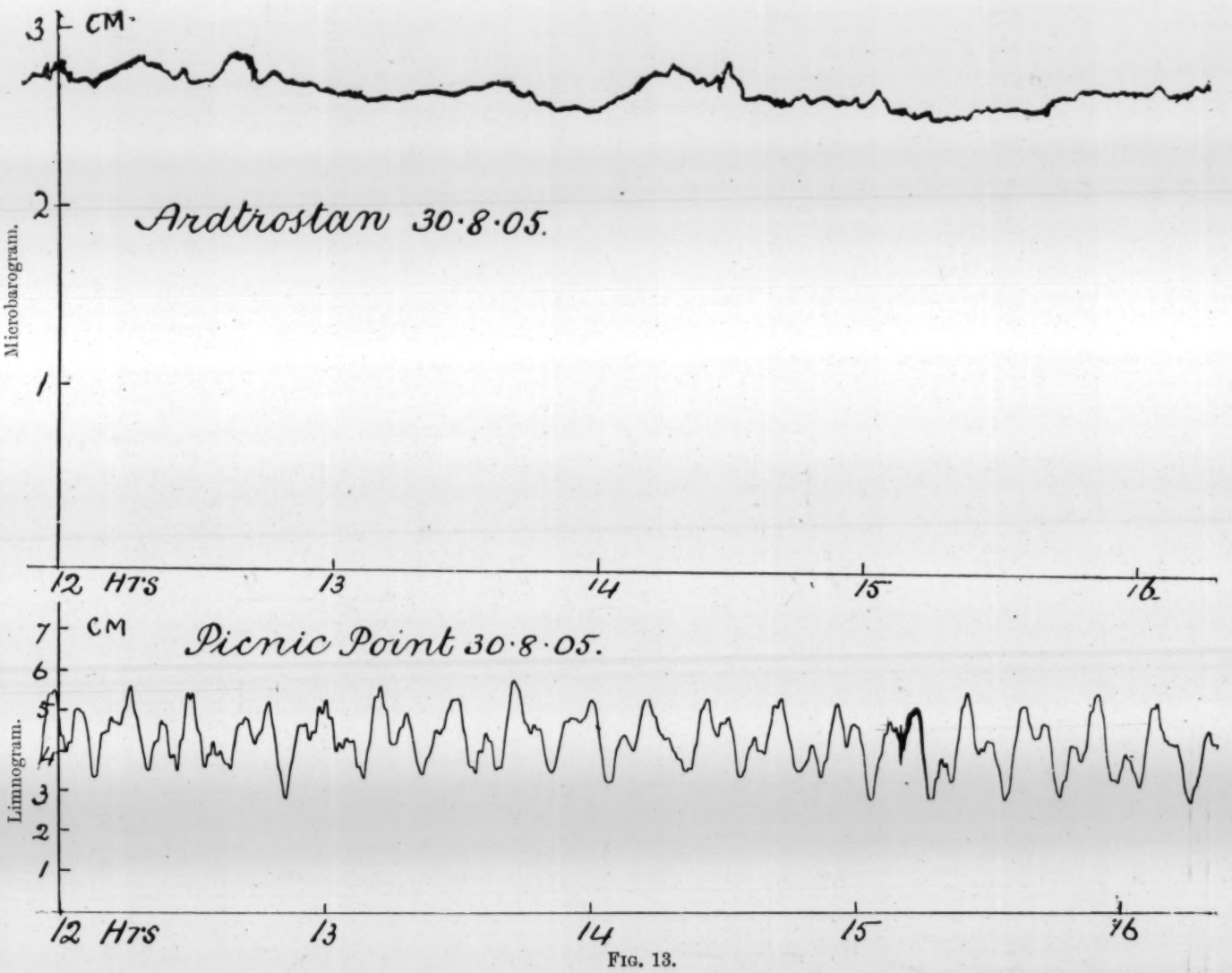



FIG. 13.

microbarograms, which has a period of 6$^m$ to 8$^m$, well marked at Killin and Lochearnhead, less clearly at Ardtrostan.

21*st August* (fig. 8).—At 1$^h$ 11$^m$ a BT-dicrote appears; and the microbarogram at Lochearnhead shows an 8$^m$ period; probably its scale is too small to show the 6$^m$ period. At 5$^h$ 37$^m$ the binodal component is much strengthened by a microbaric disturbance having a period of 8$^m$ to 8·8$^m$, which is very clearly seen at Killin. The uninodal seiche is also present, due no doubt to the periods of 15$^m$ to 13$^m$ observed at Lochearnhead.

30*th August*.—Fig. 13 shows the kind of microbaric disturbance which pro-

* See Part V., p. 514.

duces a UBT-tricrote seiche. This was the best example obtained during our observations.

*4th September*, $0^h$–$8^h$.—Fig. 14 shows a case where a strong trinodal component was introduced into a UB-dicrote by microbaric disturbances having periods of $6{\cdot}1^m$, $8{\cdot}0^m$, $8{\cdot}2^m$, $5{\cdot}1^m$.

*6th September*.—From $2^h$ to $10^h$ there was a perfectly smooth UB-dicrote, part of which is reproduced in fig. 4, vol. xlv., p. 366 of the *Transactions*. At first the uninodal component decreases and the binodal increases. Thus, at $3^h$, $2U = 11{\cdot}7$ mm., $2B = 13{\cdot}3$ mm.; at $5^h$ $30^m$, $2U = 3{\cdot}9$ mm., $2B = 15$ mm. The microbarogram shows

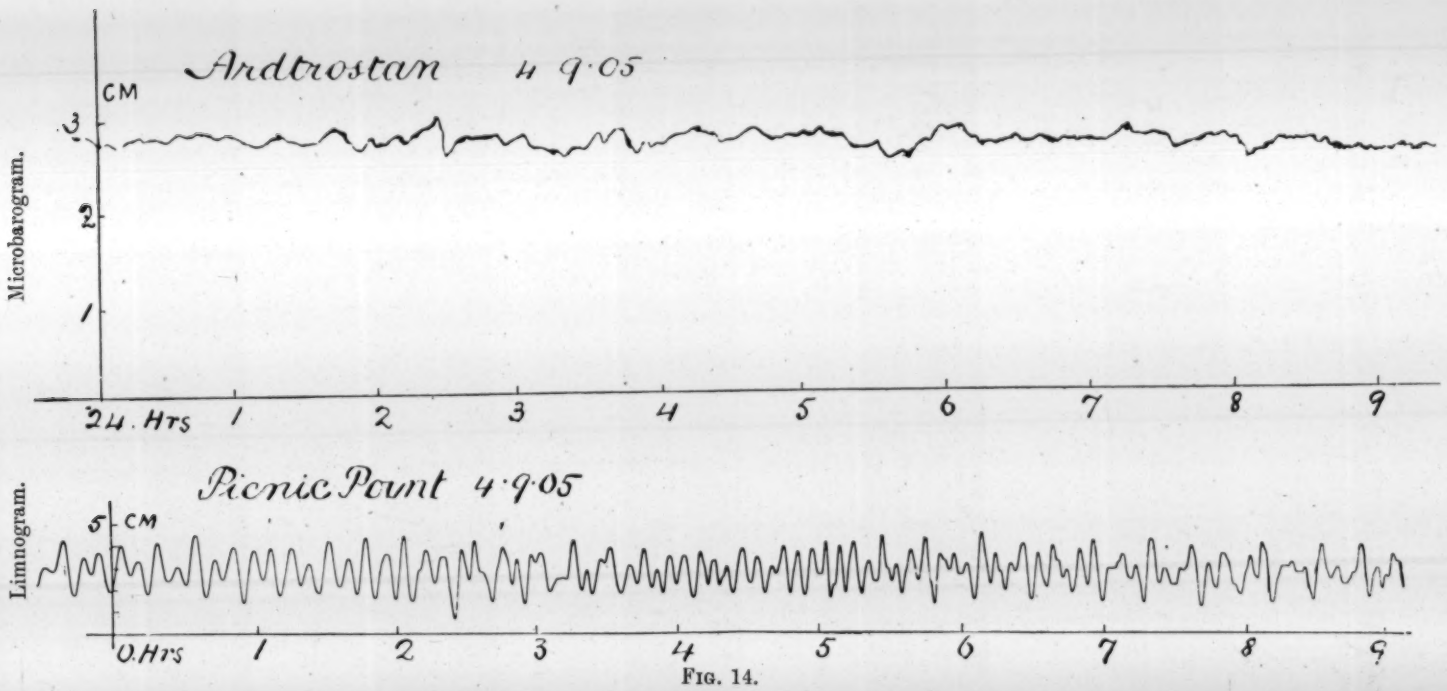



FIG. 14.

periods of $10{\cdot}7^m$ about $4^h$, and $9{\cdot}4^m$ about $6^h$, which were no doubt responsible for this gradual alteration of the seiche.

*16th September*.—About $6^h$ (see fig. 15) a succession of four very regular waves of barometric disturbance, having a period of $13{\cdot}3^m$, generated a very regular UB-dicrote, which lasted about $15^h$. The uninodal component gradually diminished, as will be seen from the following measurements:—

| Hour. | 2U. | 2B. |
|---|---|---|
| h. | mm. | mm. |
| *Ca* 10 | 22·9 | 4·5 |
| ,, 16 | 17·9 | 4·1 |
| ,, 21 | 9·8 | 4·2 |

*16th October*, $4^h$–$9^h$ (see fig. 2, above).—A very interesting example, showing both positively and negatively the effect of a periodic barometric disturbance, is

obtained by contrasting the limnograms taken simultaneously on Loch Tay at Killin, and on Loch Earn at Lochearnhead. The period of the microbaric disturbance is about 29$^m$; and it will be observed that it greatly increases the uninodal seiche of

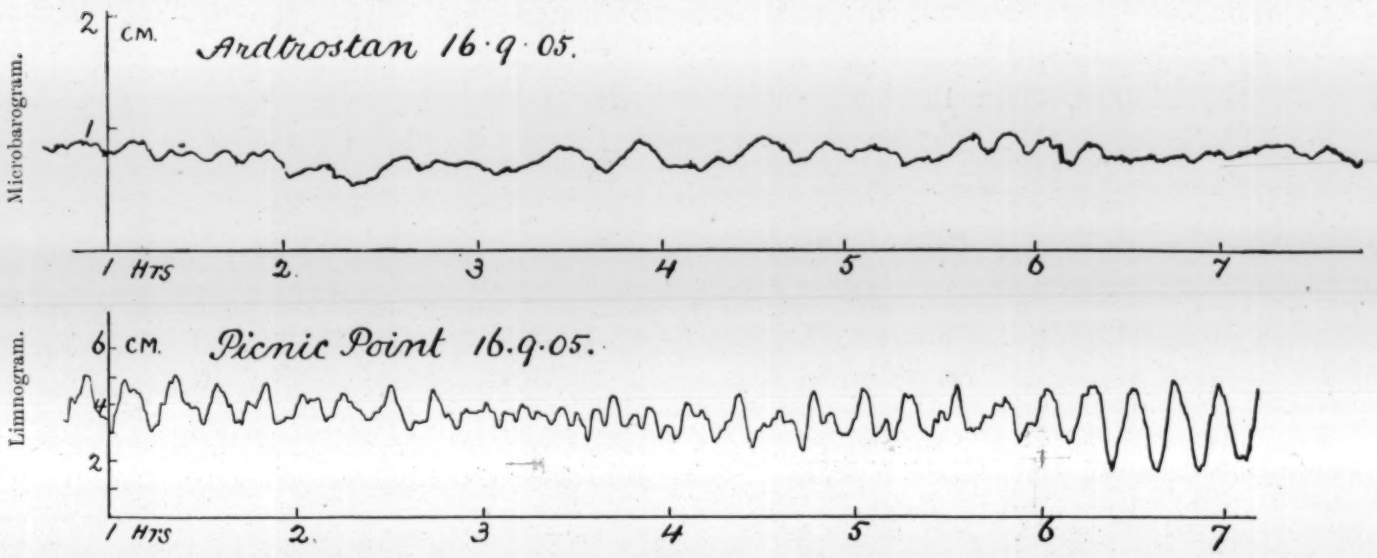



FIG. 15.

Tay, the period of which is about 28·4$^m$. Indeed, the uninodal thus produced was the best we found on Tay. On the other hand, this strong barometric disturbance produces little or no effect on the smooth UB-dicrote which was in progress on Earn, because the periods of its components are 14·52$^m$ and 8·09$^m$.

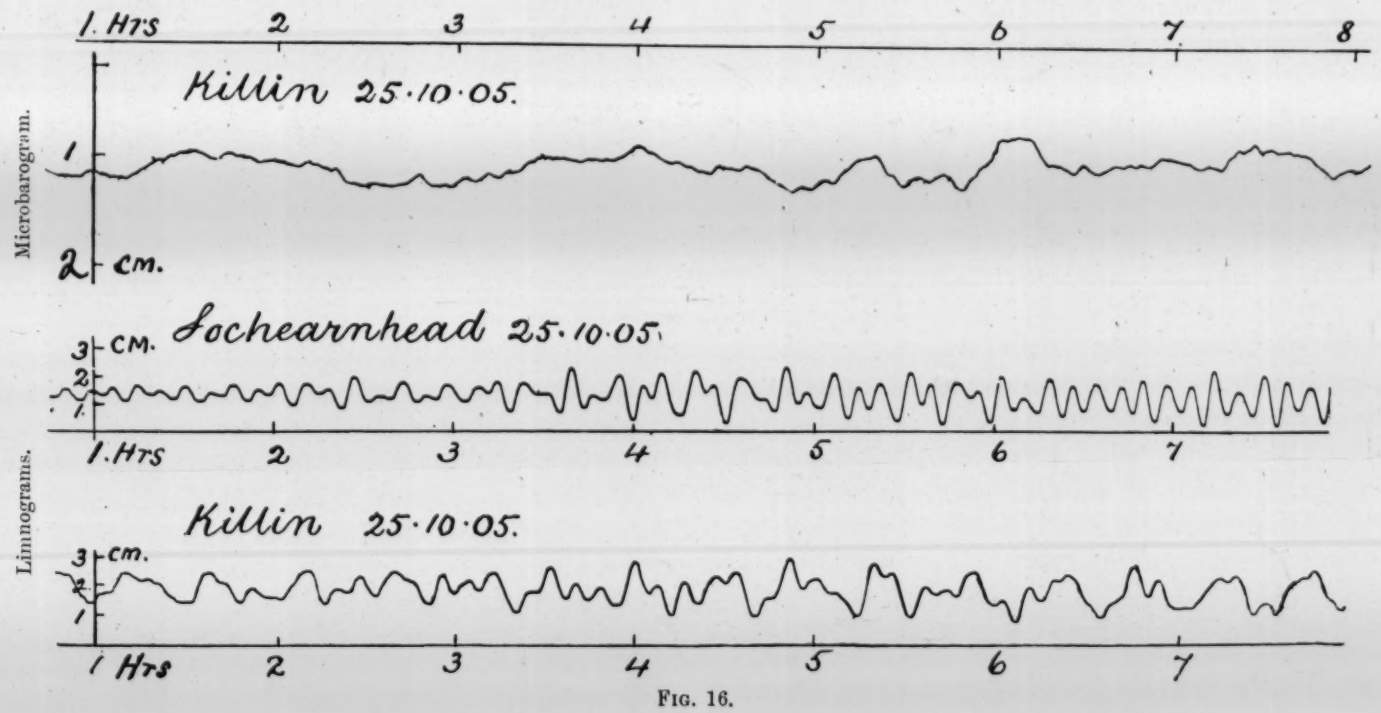



FIG. 16.

As further examples of this kind, we may also mention the following observations :—

*25th October*, 3$^h$–8$^h$ (fig. 16).—Microbaric disturbances of period 7·5$^m$ to 8·0$^m$ brought out the binodal of Earn ($T_2 = 8·09^m$) and the quadrinodal of Tay ($T_4 = 8·6^m$).

*7th December, ca.* $14^h\ 30^m$ (fig. 17).—About this hour was observed the greatest total range of seiche found on Tay, viz. 80 mm. At that moment the range on Earn, which at $8^h$ had been as much as 55 mm., was only about 25 mm. The explanation of this is doubtless to be found in the well-marked period of $26{\cdot}5^m$ shown in the microbarogram between $12^h$ and $16^h$.

*14th August.*—Fig. 18 shows an interesting case of the gradual development of a UB-dicrote seiche. The anemogram shows a fall of wind during this development;

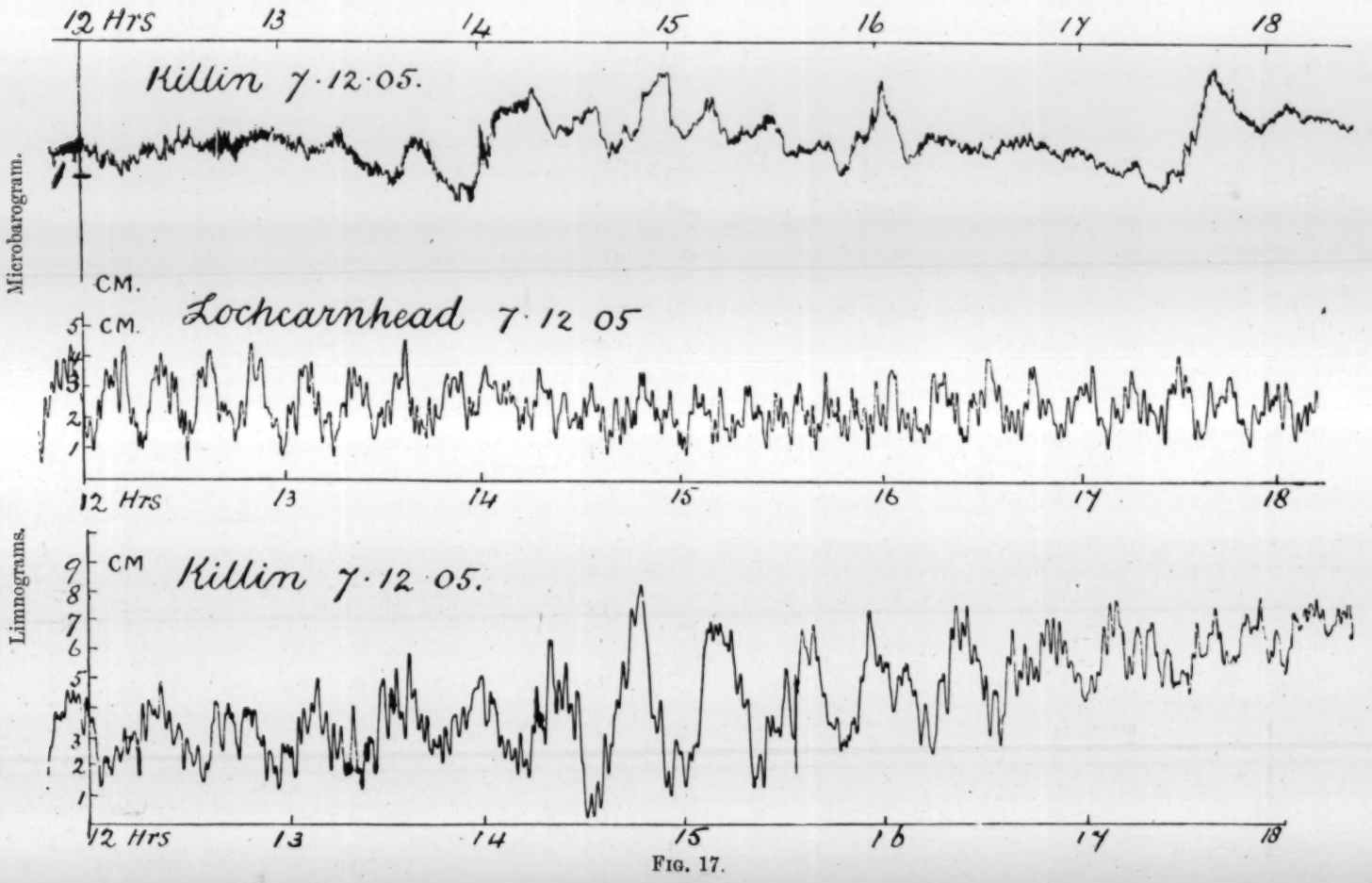



FIG. 17.

but it seems to have been too gradual to be the effective cause of the seiche. There can be little doubt that the true cause was a periodic microbaric disturbance, which is very faintly indicated in the microbarograms taken at Ardtrostan and Lochearnhead.

The present is one of many examples found in the course of our observations which prove that a lake-surface is much more sensitive to minor fluctuations of the atmospheric pressure than any barometric apparatus hitherto constructed.

We might produce many more examples; but probably the above are sufficient to establish that the synchronism of quasi-periodic disturbances of the atmospheric pressure with the seiche-periods of a lake are a frequent cause of seiches.

It is true that the resonance experiments which Nature performs in her own rough laboratory have not the nice exactitude of those we devise and carry out in a physical

institute. But then it is not the way of Nature to flaunt her beauties before the unappreciative, or to press the secret principles of her action upon the attention of the unreflecting.

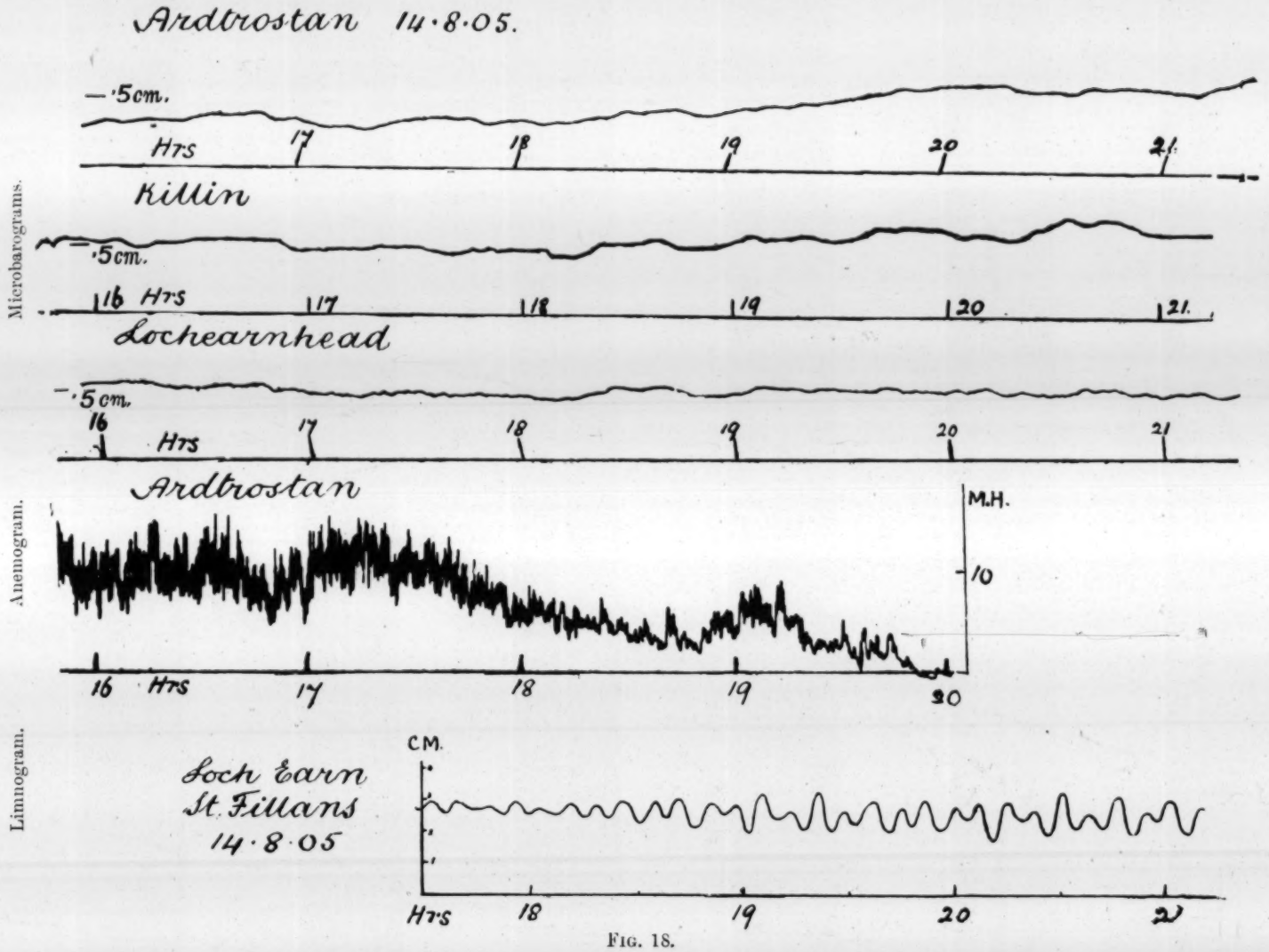



FIG. 18.

## LABORATORY EXPERIMENTS ILLUSTRATING THE ORIGIN OF SEICHES.

In a lecture * given at the Royal Institution the writer showed some experiments with a miniature parabolic lake, to illustrate the nature and origin of seiches, which seem worthy of mention here. The trough used was 12 feet long, about $2\frac{3}{4}$ inches wide, and 12 inches deep. It was fitted with a parabolic wooden bottom, and filled with slightly coloured water to a depth of about $7\frac{3}{4}$ inches.

Following a method used by Messrs WHITE and WATSON in their interesting experiments on this subject,† we found it possible, by stirring horizontally with a small paddle at the theoretical positions of the nodes and with the corresponding

* See *Proc. Roy. Inst.*, Friday, May 17, 1907.
† *Proc. R.S.E.*, vol. xxvi., p. 146 (1906).

period, regulated by means of a metronome, to generate uninodal, binodal, and trinodal seiches easily visible to a large audience.

This method of generating seiches probably does not correspond to anything observable under ordinary circumstances in a lake;* but the experiment is interesting in view of the important discovery recently made by the Japanese observers,† that the secondary oscillations in many of the bays on the coast of Japan are seiches, having a node at the mouth and a loop at the bottom of the bay. These oscillations, which are sometimes of considerable range, are apparently due to resonance with comparatively inconspicuous undulations in the external oceanic swell, the periods of which are equal to some of the natural periods of the bay.

It was also possible, by means of a trough like that above described (length, 5 feet; breadth, 4 inches; depth, 5 inches; depth of water, 3 inches), to illustrate the generation of seiches in an ordinary lake by periodic variations of the surface pressure. By laying a sheet of tin on the top of the trough, an air-channel was formed over the surface of the water. Through this channel air could be blown by means of a Blackman's fan, and, by working a slider timed by the metronome, the air-current could be made intermittent. When the whole of the surface was covered over by the sheet of tin, the effect of the current, whether steady or intermittent, was merely to generate a train of progressive surface waves, the motion due to which was shown, by dropping in a stream of red ink, to be confined to a stratum of the water near the surface. But, when only half the length of the miniature lake was covered in, an intermittent current having the proper period generated a uninodal seiche. When a strip of tin dipping into the water at the end of the covering sheet just over the middle of the water was used to block the air-current, after a few alterations of the blast the amplitude of the generated seiche was such as to cause the water to splash over the ends of the trough.

In like manner, by covering in the tank up to the theoretical position of the binode, a binodal seiche was generated, the parabolic surface of which at its culmination had about the same curvature as the parabolic bottom of the trough.

By using streams of red ink from a pipette, it was easy to demonstrate to the audience the essential nature of the seiche-motion, and to contrast it with the essentially different motions which characterise the progressive and the solitary wave.

### On the Vibrations which cause the Embroidery on the Limnogram.

To the oscillations of a lake-surface having a period of less than $2^m$, which under certain circumstances cause a regular or irregular embroidery on the limnogram, Forel gave the name of vibrations. The complete explanation of these vibrations can hardly

* Endrös, however, has given examples in point, in some cases of constricted lakes, where a seiche in one part forces a seiche of the same period in another part.

† "Secondary Undulations of Oceanic Tides," by Honda, Terada, Yoshida, and Isitani, *Journ. of the College of Science, Imperial University, Tokio*, vol. xxiv., p. 1 (1908).

be said to have been given as yet. They are, however, of great interest, because there is some reason to believe that in part at least they reflect in miniature the action of the causes which produce the storm-waves of the ocean, our knowledge of which is still far from complete, although they are of such vital importance to seafaring men.

Inasmuch as our first object was to determine as accurately as possible the seiche periods and the positions of the nodes of Loch Earn, the limited time at our command was allotted and our apparatus disposed mainly for these two purposes; and it was not until near the end of our observations, after the extemporisation of the statolimnograph, that much attention was given to the vibrations of the lake. We cannot, therefore, pretend to offer much towards a final solution of the problem of the vibrations; but we may record a few observations which seem to enhance the interest of the question, and may ultimately prove useful in its final solution.

The embroidery caused by these vibrations, as may be seen by comparing the figures of this memoir and figs. 5, 6, 7, 10, 11, 12, 16, 17, 18 of the previous memoir of this series,* varies considerably in form, and may be regular or irregular according to circumstances. It must also be remembered, as was long ago pointed out by FOREL, that, owing to the damping effect of the well and access tube, each limnograph reproduces more or less of these vibrations according to its adjustment. The statolimnograph, used with a wide access tube, owing to the very small inertia of its moving parts, is best adapted for this purpose. Compare, for example, figs. 4 or 5 of Part II. with fig. 11 of Part I.

Although occasionally the embroidery continues regular for a considerable time, and appears to have a perfectly definite period and constant or at least slowly varying range, as a rule its configuration changes rapidly, and any regularity is transient. This makes it very difficult to analyse it into harmonic components, even if analysis into a finite number of such components were possible.

In our observations the maximum range of the vibrations varied from 0 to 21 mm.; an average value might be about 6 mm. At times the range of the vibrations (*e.g.* fig. 19) exceeded the range of the seiche, so that the former quite obscured the latter.

The periods observed showed much less variation. In the limnograms taken with the Waggon recorder and Sarasin instruments, the period ran from $1{\cdot}3^m$ to $2^m$; in the statolimnograms, from $\cdot42^m$ to $\cdot79^m$. It must be remembered, however, that in the latter the short-period embroidery obscures that of longer period; and in the former the vibrations of shortest period are damped out. For the ordinary limnograms the average of the periods might be put at $1{\cdot}47^m$. The period that actually occurred oftenest in the cases we happened to examine was $1{\cdot}5^m$.

The embroidery was never observed unless there had been sufficient wind to cause progressive surface waves; and it subsided at once when these waves disappeared. The observations of HALBFASS, ENDRÖS, and others show that it is usually more marked when the limnogram is taken at the leeward end of the lake: it may be very marked there

* See *Trans. R.S.E.*, vol. xlv., pp. 366, 369, 370, 380, and 383.

and almost or altogether absent at the windward end. It also depends on the amount of shelter at the point of observation.

In most cases the occurrence of embroidery is accompanied by the characteristic wind blurring on the microbarogram, or else by fluctuations of very short period and very small range. In some cases the fluctuations could be counted; and in one or two their period seemed to coincide with the period of the lake vibrations. The sensibility of the microbarographs used and the number of interpretable cases were not sufficient, however, to justify any general conclusion.

Attempts were made to connect the periods of the lake vibrations with the periods of the wind fluctuations, as indicated on the anemogram, but without success, possibly owing to the fact that the time scale of the anemograph was so short that it was impossible to count the wind fluctuations with any certainty.

The simultaneous limnograms taken on Earn and Tay during October and November 1905 were examined to see whether there was any connection between the vibrations on the two lakes pointing to a common atmospheric cause. It was found that the average of the maximum ranges and of the periods was much the same for both lakes; but there seemed to be no connection between the occurrence of a particular range or a particular period in the two. The range might be high in both lakes and the periods different; or the periods nearly the same and the ranges different; or there might be vibrations of considerable range on one of the lakes, and none, or only the merest tremor, on the other.

Several suggestions have been or may be made regarding the nature of these lake vibrations.

1. They might be longitudinal seiches of very high nodality. This was the suggestion put forward tentatively by Forel, after trying in vain every other explanation that occurred to him.

If the period of $1{\cdot}47^{m}$ were due to a longitudinal seiche, the number of the nodes would be 12 or 13. It is easy, by regarding Earn as a symmetrical rectilinear lake,* to calculate roughly the positions of the nodes. It would therefore be possible, by means of careful experiments with two or more self-registering instruments, such as the statolimnograph, to obtain positive or negative evidence regarding the truth of the hypothesis that the vibrations are wholly or partially plurinodal longitudinal seiches.

In the present state of our knowledge the balance of evidence seems to be against this hypothesis. A plurinodal seiche is a simultaneous oscillation of the whole lake. If, therefore, a vibration were a plurinodal seiche, it should be apparent simultaneously at both ends of the lake; whereas we know that it may be present at either end and apparently absent at the other. Also, if it be a plurinodal seiche, it should be present simultaneously at nearly opposite points on the two sides of the lake. We made repeated attempts to detect correlations of phase, by stationing observers on the two sides, and signalling the maxima or minima of the vibrations, but were quite unable to

* See my memoir on the "Hydrodynamical Theory of Seiches," *Trans. R.S.E.*, vol. xli., p. 639 (1905).

establish either coincidence or opposition of phases. We also made observations with the statolimnograph at a point opposite the limnograph near the eastern binode, while the latter was running at high speed (2·96 mm. per minute). Not only were there no apparent coincidences of phase, but the binodal limnograph showed a well-marked vibration whose period was 1·35$^m$, while the best-marked period of the embroidery on the statolimnogram was ·44$^m$ to ·47$^m$.*

2. The vibrations might be transversal seiches of the lake. In a former memoir I expressed some doubt whether seiches of this kind could be stable in an elongated lake. In an elaborate and most interesting review of our present knowledge of the seiche periods of lakes in general, recently published,† Dr Endrös has stated that he has, by means of phase observations, definitely established the existence of a transversal seiche of period 1·56$^m$ in the Tachinger See, and shown that both it and the seiche between Morges and Evian, observed by Forel and suspected by him to be transversal, as well as certain other cases of the same phenomenon, agree very well with the hydrodynamical theory. My doubt on this matter must therefore be abandoned. Dr Endrös' view is that only part of an elongated lake takes part in the transversal oscillation, and that the establishment of a cross seiche is favoured by the existence of bays on the two sides of the lake, the ends of which determine the axis of the seiche. This view is strongly supported by the results of the Japanese observers regarding secondary tidal oscillations in the bays of the coast of Japan, to which we have already referred.

There remain, however, two difficulties as regards Loch Earn. I have calculated by means of the parabolic approximation the periods of the cross seiches for various breadths of Earn, and find values which average 1·85$^m$, the smallest being 1·83$^m$, the greatest 2·30$^m$. The section at the eastern binode, where the observations above referred to were made with the statolimnograph and the Sarasin limnograph, is very nearly parabolic in shape, and the period there would be 1·9$^m$ or more, which exceeds any of the periods observed in the embroidery by more than any likely error, either of observation or calculation.

Then there is the further fact, already mentioned, that no correspondence of phase could be detected, although it was anxiously looked for, and indeed at first expected.

3. Another cause of the embroidery of the limnogram may possibly be found in progressive surface waves and wave groups.

Everyone is aware that the effect of a persistent wind, which has blown for some time along a lake-surface, is to produce a progressive train of waves travelling down the wind. The height and also the length of these waves depend on the "fetch," *i.e.* the length of water over which the wind has blown, as well as on its velocity. The range and the wave-length both increase as we go "down the wind," until at last the wave-crests break and "white horses" are formed. Then a sort of dynamical equilibrium is

* See fig. 19, where the statolimnograms in question are reproduced.

† *Petermanns Geog. Mittheilungen*, Heft ii., 1908.

established, and the range and wave-length increase no longer, unless the waves run into shallow water. This progressive surface wave motion may persist for a considerable time (in the ocean for days) after the wind has fallen, in the form of swell; and it may be propagated into regions where there has been no wind. In ordinary circumstances, owing to the continual variation in the strength of the wind, and in the case of lakes probably also to reflections from the shores, at any particular moment not one train of waves is generated, but many of slightly differing wave-length and differing phases. These trains interfere and cause a succession of wave maxima, commonly called "wave groups."

Several observations of the periods of surface waves and wave groups on Loch Earn were made by counting the waves or wave maxima which passed a given point in a certain time. This is easy in the case of the wave maxima; not so easy in the case of the single waves, which have a bewildering habit of losing themselves by running into and through each other and through the maxima. Still, the results were fairly concordant. The observations were made at the eastern binode and at the Picnic Point during westerly winds of various kinds. The average of the periods for single waves was $\cdot 035^m$, the smallest and greatest values being $\cdot 024^m$ and $\cdot 045^m$. The most usual value of the period for the groups was $\cdot 5^m$ to $\cdot 66^m$, the least and greatest values observed being $\cdot 33^m$ and $1\cdot 17^m$. For the single waves ranges of 6 in. to 12 in. were common; but on one stormy day ranges of 2 ft. to 3 ft. were observed.

From a set of observations made at my request by Mr JAMES MURRAY on Loch Tay, the following data were calculated for that lake. T is the period, $\lambda$ the wave-length, and $v$ the velocity of propagation for the single waves; $T_g$, $\lambda_g$, $v_g$, the corresponding magnitudes for the wave groups. The observations were made at Killin, when there was no wind, on swell coming in from the lake and running in water 13 ft. 6 in. to 12 ft. deep.*

*For Single Waves.*

$T = \cdot 017^m$, $\lambda = 18$ ft. to 25 ft., $v = 18$ to 25 (ft./sec.) $= 12$ to 17 (mile/hour).

*For Larger Groups of 4 to 6 Maximum Waves.*

$T_g = \cdot 5^m$ to $\cdot 75^m$, $\lambda_g = 252$ ft. to 283 ft., $v_g = 8\cdot 4$ to $6\cdot 3$ (ft./sec.) $= 5\cdot 7$ to $4\cdot 3$ (mile/hour).

*For Smaller Groups of 2 to 3 Maximum Waves.*

$T_g = \cdot 083^m$ to $\cdot 17^m$, $\lambda_g = 42$ ft. to 63 ft., $v_g = 8\cdot 4$ to $6\cdot 3$ (ft./sec.) $= 5\cdot 7$ to $4\cdot 3$ (mile/hour).

It is obvious that the single waves could not cause the ordinary and most prominent periods in the embroidery, which run from about $\cdot 5^m$ to $1\cdot 5^m$; but there is no doubt that they cause the thickening or blurring of the limnogram which usually appears when the wind is high. On the other hand, the periods of the wave groups are nearly coincident with some of the more prominent periods of the embroidery. Part of this

* The velocity of a "long wave" in which would be about 20 (ft./sec.).

embroidery may therefore be due to wave groups; but more observations are required to settle the matter beyond doubt.*

4. In a paper "On the Relation between the Velocity of the Wind and the Dimension of Oceanic Waves, with an Explanation of the Waves of Longer Period on Open Coasts,"† Professor BÖRGEN has suggested that the secondary tidal oscillations and waves of unusually long periods occasionally observed on open coasts, where the circumstances do not seem to justify the assumption of a seiche, may be due to difference and summation waves (whose theoretical existence arises from the non-applicability of the theory of the linear superposition of small motions), after the analogy of the difference and summation tones of HELMHOLTZ. It is quite possible that some such explanation may apply in part to lake vibrations; but we have no evidence to produce for or against such a hypothesis.

5. Towards the end of our survey of Loch Earn, we made some observations with the statolimnograph (unfortunately we had time to make only a few) which point to yet another explanation of some part, especially the more irregular part, of the embroidery on the limnograph.

In fig. 19 are placed together two statolimnograms, which were taken in close succession at two stations near to each other on the northern shore of Loch Earn, during a moderate westerly breeze [mean velocity 12 to 16 (mile/hour), extreme velocity occasionally 24 (mile/hour)]. The upper one was taken in a sheltered bay to leeward of the delta of the Glentarken Burn, the lower about 100 yards farther west, to windward of the delta. The bay was comparatively calm, disturbed only by the swell propagated into it from the wind waves rolling outside. The difference between the two limnograms is very striking. The maximum range of the embroidery to windward is much greater, and the pattern is much more irregular and complicated. What

* It is much to be desired that further observations should be made on the period, wave-length, and velocity of propagation of single waves and wave groups, in lakes, on sea-coasts, and in the open sea. Sailors have many opportunities for such observations; and physicists might devote some attention to the matter, when they take an open-air vacation from the ardent pursuit of the electron.

It is curious how ignorant we still are regarding some of the most important hydrodynamical phenomena, notwithstanding something like a century and a half of continued researches, both mathematical and experimental. We know very little, for example, regarding the action by which the wind increases the range and the length of the waves as we pass to windward.

We are told,[1] and it is easy to understand, that a wind whose velocity is greater than the velocity of progression of a train of waves must increase their range; but what is the explanation of the increase of wave-length? Observations, some of which are mentioned below, have strongly suggested the following as the *modus operandi*:—The dynamic instability of the surface after the wind has reached a certain velocity leads to the generation of wave trains of slightly varying length and phase. These trains interfere and produce wave maxima The wind, so long as it travels faster than the wave maxima, will increase the range of the waves near the maxima more than elsewhere. Thus the periodically occurring wave maxima will be elevated into independent wave trains no longer resolvable into the previous harmonic components. Thus a new train of progressive waves will be formed of considerably greater mean range and mean wave-length than before, but of slightly differing ranges and wave-lengths. These again will interfere, and through the action of the wind generate other trains of still greater mean range and mean wave-length; and so on, until the process is stopped by the breaking of the wave crests. This is merely a speculation, without sufficient basis, either theoretical or experimental; but the subject seems to call for investigation, and its practical importance is undeniable.

† *Annalen der Hydrographie und maritimen Meteorologie*, Heft i., Jan. 1890.

[1] See Lamb's *Hydrodynamics*, p. 569 (1906).

remains to leeward has much the same prominent periods as we observe to windward, viz. ·4$^{m}$ to ·5$^{m}$; but it is obvious that the intervening promontory has screened off a great

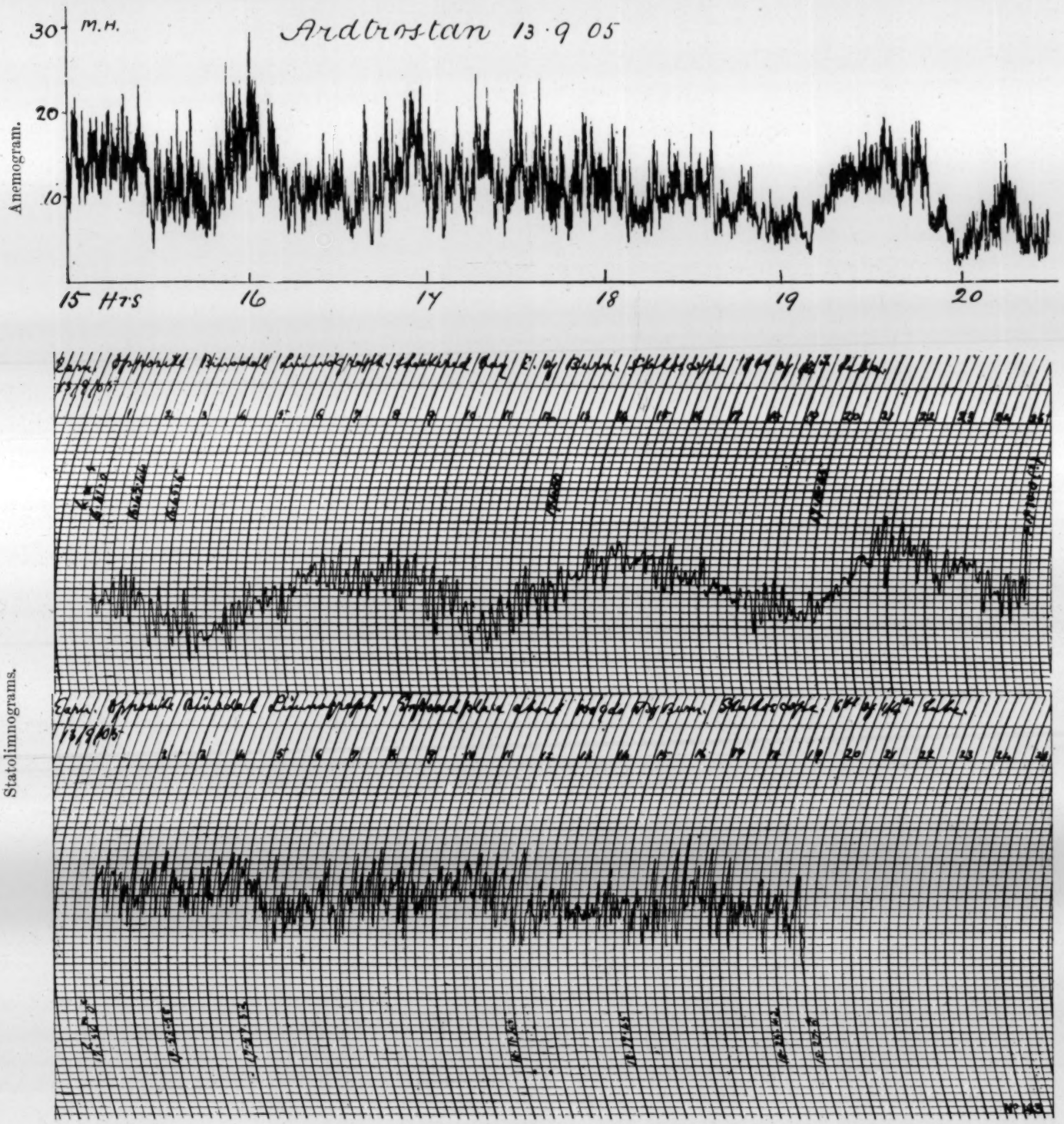



FIG. 19.

part of the vibrations. The part thus screened off could only consist of surface waves of short length, and could not consist either of longitudinal or of transverse seiches.

Again, I often watched the statolimnograph slowly inscribing indentations, such as

those which are so marked in the lower limnogram in fig. 19, and noticed over and over again that it would set one down in an interval of total or comparative calm. On looking to windward when this happened, a black line would be seen on the water some distance off, indicating a coming wind-squall; then presently would be heard the rustle of the wind in the trees overhead; and the increased prattle of the waves among the pebbles on the beach would show that the squall had reached the observer. In short, the lake vibration had gone before, and the wind had followed after. The explanation seems to be that the squall exerts a horizontal traction on the water and causes a drift current. By and by this current becomes greater than the compensating return current underneath. Thus a hump (or a group of waves) is raised on the surface, which is propagated in the water with a speed usually exceeding the velocity of the wind in a moderate breeze. We have here, in fact, in small a phenomenon with which sailors are familiar

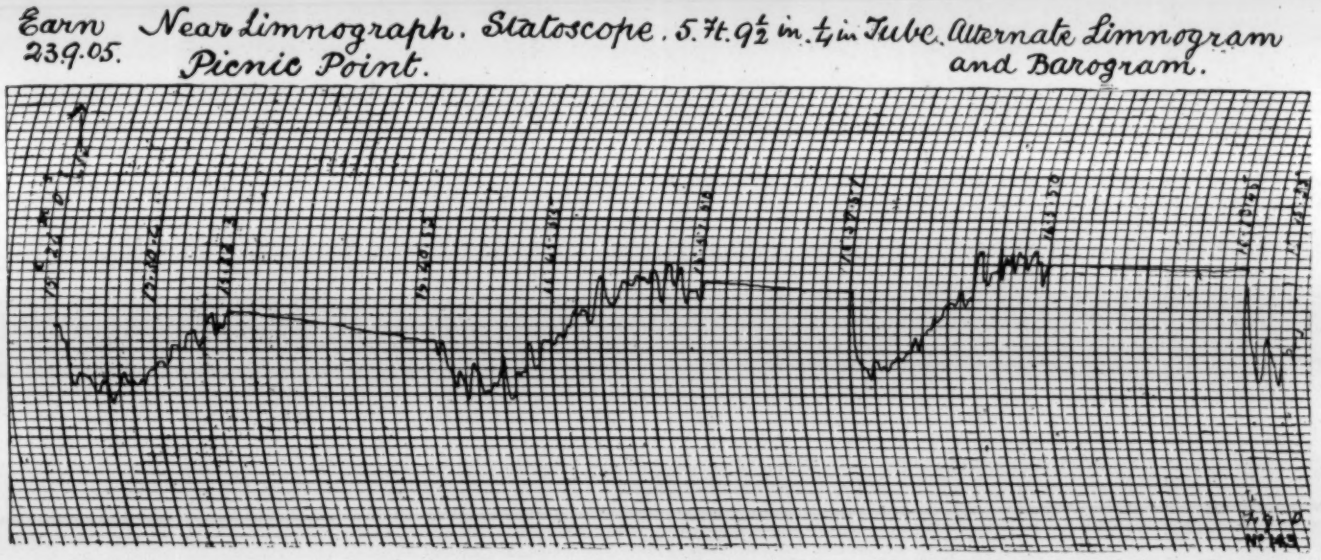



FIG. 20.

on a large scale, when they point to the long swell which records or presages a distant storm at sea.

I obtained a striking confirmation of this view in the course of an observation planned to test a totally different hypothesis. I had supposed that the vibrations might be due to some extent to simultaneous abrupt or periodic disturbances of the atmospheric pressure. As explained in Part I. of this report,* the statolimnograph can be used in rapid alternation as a limnograph and as a microbarograph. Fig. 20 shows the result of an observation of this kind.† The limnogram is deeply embroidered; the microbarogram is all but straight. Since the sensitiveness of the Richard statoscope is fifteen to twenty times that of a mercury barometer, the ordinate of the microbarogram represents the air-pressure on a larger scale than a water barometer. If we allow for the damping effect of the well and access tube on the half-minute vibrations, we shall

* *Trans. R.S.E.*, vol. xlv., p. 368 (1906).

† Another is given in Part I. of this report, *Trans. R.S.E.*, vol. xlv., p. 370, fig. 12 (1906).

be under the mark if we admit that the statolimnograph magnified the range of these vibrations three times. The obvious conclusion is that there was no disturbance of the atmospheric pressure of an order sufficient to cause directly the embroidery observed on the limnogram. It follows that it must have been due to some cumulative atmospheric cause whose action originated at a distance from the observers, and I am inclined to look for this cause in the surface waves, solitary or periodic or quasi-periodic, caused by the heaping action of the wind. It is, of course, obvious that such action as this would be screened off by a promontory or an island, and would be most marked at the windward end of a lake. This cause was suggested, under the name of *Windstau*, by Endrös in his classical memoir on the complicated seiches of the Chiemsee, which has done so much to enlarge our knowledge of lake oscillations.

Before concluding this part of my report, I must say a word or two in recognition of the services of those who assisted us in our seiche survey.

In the first place, thanks are due to Mr Laurence Pullar, whose generosity furnished the greater part of the money required for our undertaking.

We have also to thank the Government Grant Committee of the Royal Society of London, for giving us a grant for the hire and instalment of meteorological apparatus; and Mr W. N. Shaw, Director of the Meteorological Office, for much sympathy, which went the length of a visit to Loch Earn, and even to manual assistance in the erection of some of our instruments.

To the constructive skill and practical scientific capacity of Mr James Murray we owed the overcoming of many of our early difficulties, and also some of our best observations.

Messrs P. White and W. Watson, who were specially attached to the Lake Survey for our work during August and September 1905, worked throughout with the greatest zeal and good judgment. Most of the meteorological observations and nearly all of the later observations with the index limnographs were made by them.

Mr Macdonald, Schoolmaster, and Mr Thornton, Postmaster, Lochearnhead, and also the Postmistress at St Fillans, kindly assisted us by taking charge of barographs; and the Stationmasters at Lochearnhead and Balquhidder did their best to give us correct time.

The proprietors of the shores of Loch Earn most courteously allowed us to instal our fixed instruments in the most suitable places. In particular, Colonel Stewart of Ardvoirlich not only allowed us to put up our limnographs on his property, but permitted us to cut wood for the staging, and furnished us with information regarding the daily rainfall at Ardvoirlich.

The photographic reproduction of the figures in this report was in many cases difficult, owing to the faintness of some of the records, in all cases tedious, owing to the troublesome adjustment of scale. The patient intelligence devoted to this part of the work by the firm of Hislop & Day deserves the highest praise.

Finally, I must apologise to the Trustees of the Lake Survey and to those who assisted in the Seiche Survey for the long delay in the completion of the report. This delay has been due to the heavy pressure of unavoidable professional and public duties that has fallen upon me during the three years that have passed since the pleasant autumn when we worked together upon Loch Earn.

## PART V.

## MATHEMATICAL APPENDIX ON THE EFFECT OF PRESSURE DISTURBANCES UPON THE SEICHES IN A UNIFORM PARABOLIC LAKE.

### Estimation of the Effect of Pressure Disturbances on the Seiches in a Symmetric Parabolic Lake of Uniform Breadth.

1. In what follows I shall use the method of *Normal Co-ordinates* introduced by Lord Rayleigh,* to which reference was made in my memoir on the Hydrodynamical Theory of Seiches, § 21.†

With very slight and obvious modifications, the notation employed is the same as in the memoir just referred to, and, to make the results approximately applicable to Loch Earn, it may be supposed that the length, $2a$, of the symmetric parabolic lake is 6 miles, say $10^6$ cm., and the maximum depth 270 feet, say 8000 cm. Unless the contrary is indicated, C.G.S. units are used throughout.

Then we have, if $\xi$ and $\zeta$ be the horizontal and vertical displacement at time $t$ of a particle on the surface of the lake,

$$(1-w^2)\xi = u = -\Sigma a k_\nu \cos n_\nu(t-\tau_\nu) Q_\nu(w) \quad . \quad . \quad . \quad . \quad (1),$$

$$\zeta = +\Sigma k_\nu \cos n_\nu(t-\tau_\nu) Q'_\nu(w) \quad . \quad . \quad . \quad . \quad (2),$$

where $n_\nu^2 = gh\nu(\nu+1)/a^2$, $w = x/a$; $k_\nu$ is the extreme amplitude of the $\nu$-nodal seiche corresponding to $x = +a$, *i.e.* to $w = +1$; and $Q_\nu(w)$ is a solution of the equation

$$(1-w^2)Q''_\nu(w) + \nu(\nu+1)Q_\nu(w) = 0 \quad . \quad . \quad . \quad . \quad (3),$$

which vanishes when $w = \pm 1$, and is such that $Q'_\nu(1) = 1$.

It is convenient for our present purposes to use the forms of the Seiche Functions for which $c = \nu(\nu+1)$, given by Dr Halm,‡ viz.—

$$Q_\nu(w) = \frac{1}{2^\nu \nu!} \frac{d^{\nu-1}}{dw^{\nu-1}}(w^2-1)^\nu \quad . \quad . \quad . \quad . \quad (4),$$

$$Q'_\nu(w) = \frac{1}{2^\nu \nu!} \frac{d^\nu}{dw^\nu}(w^2-1)^\nu \quad . \quad . \quad . \quad . \quad (5).$$

* *Theory of Sound*, vol. i., § 87 (1877).
† *Trans. R.S.E.*, vol. xli. (1905).
‡ *Ibid.*, p. 660 (1905).

The following table gives the values of $Q_\nu(w)$ and $Q'_\nu(w)$ for the first five values of $\nu$ :—

| $\nu$ | $Q_\nu(w)$ | $Q'_\nu(w)$ |
|---|---|---|
| 1 | $\frac{1}{2}(w^2-1)$ | $w$ |
| 2 | $\frac{1}{2}(w^3-w)$ | $\frac{1}{2}(3w^2-1)$ |
| 3 | $\frac{1}{8}(5w^4-6w^2+1)$ | $\frac{1}{2}(5w^3-3w)$ |
| 4 | $\frac{1}{8}(7w^5-10w^3+3w)$ | $\frac{1}{8}(35w^4-30w^2+3)$ |
| 5 | $\frac{1}{16}(21w^6-35w^4+15w^2-1)$ | $\frac{1}{8}(63w^5-70w^2+15w)$ |

It will be observed that $Q'_\nu(w)$ is the zonal harmonic of the $\nu^{\text{th}}$ order; so that $Q_\nu(\pm 1)=0$, $Q_{2p}(0)=0$, $Q_{2p-1}(0)=(-1)^p 1\cdot 3 \ldots (2p-3)/2^p p!$; and $Q'_\nu(1)=1$, $Q'_\nu(-1)=(-1)^\nu$, $Q'_{2p-1}(0)=0$, $Q'_{2p}(0)=1\cdot 3 \ldots (2p-1)/2\cdot 4 \ldots 2p$.

If now we put

$$\left.\begin{aligned}\phi_\nu &= ak_\nu \cos n_\nu(t-\tau_\nu),\\ &= A_\nu \cos n_\nu t + B_\nu \sin n_\nu t\end{aligned}\right\} \quad \ldots \quad (6),$$

we may write the general equations which represent the motion of the lake in the case where the atmospheric pressure is uniform

$$h(1-w^2)\xi = u = -\Sigma\phi_\nu Q_\nu(w) \quad \ldots \quad (7),$$

$$\zeta = +\sum \frac{\phi_\nu}{a} Q'_\nu(w) \quad \ldots \quad (8);$$

and $\phi_1, \phi_2, \ldots, \phi_\nu, \ldots$, infinite in number, may be regarded as the *normal co-ordinates* of the *motion* in LORD RAYLEIGH'S sense of the phrase.

If $\mathfrak{T}$ be the kinetic and $\mathfrak{V}$ the potential energy in the case just supposed, we have

$$\mathfrak{T} = \tfrac{1}{2}\int_{-a}^{+a} dx h(1-x^2/a^2)\dot{\xi}^2,$$

$$= \frac{a}{2h}\int_{-1}^{+1} \frac{dw}{1-w^2}\{\Sigma\dot{\phi}_\nu Q_\nu(w)\}^2,$$

$$= \frac{a}{2h}\int_{-1}^{+1} \frac{dw}{1-w^2}\Sigma\dot{\phi}_\nu^2\, Q_\nu^2(w);$$

that is,

$$\mathfrak{T} = \tfrac{1}{2}\Sigma a_\nu \dot{\phi}_\nu^2 \quad \ldots \quad (9),$$

where

$$a_\nu = \frac{a}{h}\int_{-1}^{+1} \frac{dw Q_\nu^2(w)}{1-w^2} \quad \ldots \quad (10)$$

Since the co-ordinates $\phi_1, \phi_2, \ldots$ are normal, the products $\dot{\phi}_r\dot{\phi}_s$ do not appear in the expression for $\mathfrak{T}$.

Also, the zero configuration being the lake at rest, we have

$$\mathfrak{V} = +\tfrac{1}{2}g\int_{-a}^{+a} dx\zeta^2,$$
$$= +\frac{g}{2a}\int_{-1}^{+1} dw\{\Sigma\phi_\nu Q'_\nu(w)\}^2,$$
$$= +\frac{g}{2a}\int_{-1}^{+1} dw\Sigma\phi_\nu{}^2 Q'_\nu(w)^2,$$

since the co-ordinates are normal,

$$= +\tfrac{1}{2}\Sigma b_\nu\phi_\nu{}^2 \quad . \quad . \quad . \quad . \quad . \quad (11),$$

where

$$b_\nu = \frac{g}{a}\int_{-1}^{+1} dw Q'_\nu(w)^2 \quad . \quad . \quad . \quad . \quad . \quad (12).$$

By a well-known property of the zonal harmonic, $\int_{-1}^{+1} dw Q'_\nu(w)^2 = 2/(2\nu+1)$.

Hence

$$b_\nu = \frac{2g}{(2\nu+1)a} \quad . \quad . \quad . \quad . \quad . \quad (13).$$

Since the hypothesis of long waves involves the neglect of the squares and products of $\phi_1, \phi_2, \ldots; \dot{\phi}_1, \dot{\phi}_2, \ldots$ in the equations of motion, the Lagrangian equations for the motion of the lake reduce to

$$\frac{d}{dt}\left(\frac{\partial\mathfrak{T}}{\partial\dot{\phi}_\nu}\right) + \frac{\partial\mathfrak{V}}{\partial\phi_\nu} = 0 \quad (\nu = 1, 2, \ldots) \quad . \quad . \quad . \quad . \quad (14);$$

that is to say

$$a_\nu\ddot{\phi}_\nu + b_\nu\phi_\nu = 0 \quad (\nu = 1, 2, \ldots) \quad . \quad . \quad . \quad . \quad (15).$$

Since (15) must be satisfied by $\phi_\nu = ak_\nu \cos n_\nu(t-\tau_\nu)$, we must have

$$a_\nu = b_\nu/n_\nu{}^2,$$
$$= \frac{2a}{h\nu(\nu+1)(2\nu+1)} \quad . \quad . \quad . \quad . \quad . \quad (16).*$$

2. *Effect of a Uniform Excess of Pressure $\partial p$ over a Part of the Lake.*—Let us now suppose that an excess of pressure of $\partial p$ (measured in cm. of water) extends from the point corresponding to $w = \lambda$ to the point corresponding to $w = \mu$, and that this excess begins at $t = 0$ and ends at $t = \mathrm{T}$.

In the analysis everything will be as before, except that there will be an addition to the potential energy of

$$g\partial pa\int_\lambda^\mu dw\zeta = g\partial p\int_\lambda^\mu dw\Sigma\phi_\nu Q'_\nu(w).$$

* It follows, of course, that $\int_{-1}^{+1}\frac{dw Q_\nu{}^2}{1-w^2} = \frac{2}{\nu(\nu+1)(2\nu+1)}$, which may be readily verified independently.

Hence we shall now have

$$\mathfrak{V} = \tfrac{1}{2}\Sigma b_\nu \phi_\nu^2 + \Sigma e_\nu \phi_\nu \quad . \quad . \quad . \quad . \quad . \quad (17),$$

where $b_\nu$ has the same value as before; and

$$e_\nu = g\partial p\{Q_\nu(\mu) - Q_\nu(\lambda)\} \quad . \quad . \quad . \quad . \quad . \quad (18).$$

The equations for the motion of the lake from $t=0$ to $t=T$ are now

$$a_\nu\ddot{\phi}_\nu + b_\nu\phi_\nu + e_\nu = 0 \quad (\nu = 1, 2, \ldots) \quad . \quad . \quad . \quad . \quad (19);$$

and from $t=T$ onwards

$$a_\nu\ddot{\phi}_\nu + b_\nu\phi_\nu = 0 \quad (\nu = 1, 2, \ldots) \quad . \quad . \quad . \quad . \quad (20),$$

as before, with the condition that the values of $\phi_\nu$ and $\dot{\phi}_\nu$ must be continuous when $t=T$.

Since our equations of motion are all linear, and (15) are linear and homogeneous, any admissible solution of (15) may be added to any solution of (19). It will therefore be convenient first to find the integral equations of motion corresponding to our supposed disturbance operating upon a lake initially wholly at rest. If we superpose upon this motion that represented by the equations (6), (7), (8), we shall obtain the integral equations of motion (after $t=T$) corresponding to our disturbance when it operates on a lake in which the initial motion is given by

$$\left.\begin{aligned} \zeta &= \Sigma k_\nu Q'_\nu(w)\cos n_\nu\tau_\nu, \\ \dot{\zeta} &= -\Sigma k_\nu n_\nu Q'_\nu(w)\sin n_\nu\tau_\nu \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (21).$$

The general solutions of (19) and (20) are

$$\phi_\nu = A'_\nu\cos n_\nu t + B'_\nu\sin n_\nu t - B_\nu/b_\nu \quad (\nu = 1, 2, \ldots),$$

and

$$\phi_\nu = A''_\nu\cos n_\nu t + B''_\nu\sin n_\nu t \qquad (\nu = 1, 2, \ldots),$$

where $A'_\nu$, $B'_\nu$, $A''_\nu$, $B''_\nu$ are constants to be determined by the conditions that $\zeta$ and $\dot{\zeta}$ shall vanish when $t=0$, and be continuous when $t=T$.

We thus get

$$\zeta = \Sigma f_\nu(1 - \cos n_\nu t)Q'_\nu(w) \quad . \quad . \quad . \quad . \quad . \quad (22),$$

where

$$\frac{e_\nu}{ab_\nu} = f_\nu = -\tfrac{1}{2}(2\nu+1)\partial p\{Q_\nu(\mu) - Q_\nu(\lambda)\} \quad . \quad . \quad . \quad . \quad (23),$$

when $0 \leqslant t \leqslant T$; and

$$\left.\begin{aligned} \zeta &= \Sigma f_\nu\{-(1-\cos n_\nu T)\cos n_\nu t + \sin n_\nu T \sin n_\nu t\}Q'_\nu(w), \\ &= 2\Sigma f_\nu \sin\left(\frac{n_\nu T}{2}\right)\sin n_\nu(t - \tfrac{1}{2}T)Q'_\nu(w) \end{aligned}\right\} \quad . \quad . \quad . \quad (24),$$

when $t \geqslant T$.

From the second form of the equation (24) it follows (as is otherwise obvious) that, *cæteris paribus*, the disturbing effect on the $\nu$-nodal seiche is greatest when $T = \pi/n_\nu$, *i.e.* when T is half the period of the $\nu$-nodal seiche.

3. *General Case.*—If now we suppose that initially the extreme amplitudes of the

component seiches are $k_1$, $k_2$, . . . . and the phases $\tau_1$, $\tau_2$, . . . . , we get by superposition the general solution for the motion when $t \geqslant T$ :

$$\left.\begin{aligned}\zeta &= \Sigma[k_\nu \cos n_\nu(t-\tau_\nu) + f_\nu\{-(1-\cos n_\nu T)\cos n_\nu t + \sin n_\nu T \sin n_\nu t\}]Q'_\nu(w),\\ &= \Sigma[\{k_\nu \cos n_\nu\tau_\nu - f_\nu(1-\cos n_\nu T)\}\cos n_\nu t + \{k_\nu \sin n_\nu\tau_\nu + f_\nu \sin n_\nu T\}\sin n_\nu t]Q'_\nu(w),\\ &= \Sigma k'_\nu \cos n_\nu(t-\chi_\nu)Q'_\nu(w);\end{aligned}\right\} \quad . \quad (25),$$

where

$$\left.\begin{aligned}\tan n_\nu\chi_\nu &= \frac{k_\nu \sin n_\nu\tau_\nu + f_\nu \sin n_\nu T}{k_\nu \cos n_\nu\tau_\nu - f_\nu(1-\cos n_\nu T)},\\ \tan n_\nu(\chi_\nu - \tau_\nu) &= \frac{2f_\nu \sin\left(\frac{n_\nu T}{2}\right)\cos n_\nu(\tau_\nu - \tfrac{1}{2}T)}{k_\nu + 2f_\nu \sin\left(\frac{n_\nu T}{2}\right)\sin n_\nu(\tau_\nu - \tfrac{1}{2}T)};\\ k'^2_\nu &= k_\nu^2 + 2k_\nu f_\nu\{\cos n_\nu(\tau_\nu - T) - \cos n_\nu\tau_\nu\} + 2f_\nu^2(1-\cos n_\nu T),\\ &= k_\nu^2 + 4k_\nu f_\nu \sin\left(\frac{n_\nu T}{2}\right)\sin n_\nu(\tau_\nu - \tfrac{1}{2}T) + 4f_\nu^2 \sin^2\left(\frac{n_\nu T}{2}\right)\end{aligned}\right\} \quad . \quad (26).$$

The maximum value of $k'_\nu$ for a given value of T is therefore given by taking $\sin n_\nu(\tau_\nu - \frac{1}{2}T) = \pm 1$. We then have

$$k'_\nu = k_\nu + 2\left|f_\nu \sin\left(\frac{n_\nu T}{2}\right)\right|.$$

The phase disturbance is then zero.

4. *Particular Cases.*—Suppose $T = \pi/n_1 = \frac{1}{2}T_1$, $\tau_1 = 0$, $\lambda = 0$, $\mu = +1$, which gives us a disturbance extending over the positive half of the lake, and beginning when the uninodal seiche is at its maximum extreme amplitude and lasting for half the uninodal period.

Then

$$f_1 = -\tfrac{3}{4}\partial p, \quad f_2 = 0, \quad f_3 = +\tfrac{7}{16}\partial p, \quad f_4 = 0.$$

Hence the seiches of even nodality are all unaffected; and, if we denote the uninodal, trinodal, etc. components by $\zeta_1$, $\zeta_3$, . . . . , we have

$$\begin{aligned}\zeta_1 &= (k_1 + \tfrac{3}{2}\partial p)Q'_1(w)\cos n_1 t;\\ \zeta_2 &= k_2 Q'_2(w)\cos n_2(t-\tau_2);\\ \zeta_3 &= \left\{k_3 - \tfrac{7}{8}\partial p \sin\left(\frac{n_3\pi}{2n_1}\right)\right\}Q'_3(w)\cos n_3(t-\tau_3),\end{aligned}$$

where we have determined $\tau_3$ so that the disturbance of the trinodal component shall be the greatest possible.

Since $n_3/n_1 = \sqrt{(c_3/c_1)} = \sqrt{6} = 2{\cdot}450$, and $\sin(n_3\pi/2n_1) = {\cdot}687$, we have in the case of maximum disturbance

$$\zeta_3 = (k_3 + {\cdot}601\partial p)Q'_3(w)\cos n_3(t-\tau_3).$$

It is unnecessary to set down more formulæ, but the following table will give an idea of the effect of various kinds of uniform pressure disturbances on the uninodal, binodal, and trinodal seiche components. B and B′ denote the two binodes, U the uninode, T the trinode, and A the positive end of the lake. $\partial k_\nu$ denotes the increase

of the extreme amplitude of the $\nu$-nodal seiche in the case where the phase is such that the increase (due to the disturbance of pressure $\partial p$ lasting for a time T) is a maximum.

| T | Extent. | $2f_1/\partial p$ | $2f_2/\partial p$ | $2f_3/\partial p$ | $\partial k_1/\partial p$ | $\partial k_2/\partial p$ | $\partial k_3/\partial p$ |
|---|---|---|---|---|---|---|---|
| $\frac{1}{2}T_1$ | UA | −1·500 | 0 | ·875 | 1·500 | 0 | ·601 |
| $\frac{1}{2}T_2$ | BA | −1·000 | − ·962 | ·388 | ·787 | ·962 | ·309 |
| ,, | UB | − ·500 | ·962 | 1·264 | ·394 | ·962 | 1·006 |
| ,, | B′B | 0 | −1·925 | 0 | 0 | 1·925 | 0 |
| $\frac{1}{2}T_3$ | TA | − ·600 | − ·775 | − ·700 | ·359 | ·695 | ·700 |
| ,, | UT | − ·900 | − ·775 | 1·575 | ·538 | ·695 | 1·575 |

5. *Disturbance caused by a suddenly generated Distribution of Pressure, given by the Law* $\partial p = f(w)$, lasting from $t = 0$ *to* $t = T$.—The only supposition we shall make is that $f(w)$ is expansible in a series of zonal harmonics; so that we have

$$\partial p = \Sigma q_\nu Q'_\nu(w) \quad . \quad . \quad . \quad . \quad . \quad (27),$$

where

$$q_\nu = \tfrac{1}{2}(2\nu+1)\int_{-1}^{+1} dw f(w) Q'_\nu(w).*$$

The addition to the potential energy $\mathfrak{V}$ due to this distribution of pressure is given by

$$ga\int_{-1}^{+1} dw \partial p \zeta = g\int_{-1}^{+1} dw \{\Sigma q_\nu Q'_\nu(w)\}\{\Sigma \phi_\nu Q'_\nu(w)\}.$$

Now, since $\int_{-1}^{+1} dw Q'_\mu(w) Q'_\nu(w) = 0$ if $\mu \neq \nu$, we have

$$ga\int_{-1}^{+1} dw \partial p \zeta = \Sigma e_\nu \phi_\nu,$$

where

$$e_\nu = g q_\nu \int_{-1}^{+1} dw \{Q'_\nu(w)\}^2,$$
$$= 2g q_\nu/(2\nu+1) \quad . \quad . \quad . \quad . \quad . \quad . \quad (28).$$

It follows that the formulæ (22), (24), (25), (26) are all applicable to the general case now under discussion, the only difference being that $f_\nu$ is now given by the equation

$$f_\nu = -\frac{e_\nu}{a b_\nu} = -\frac{2g q_\nu}{2\nu+1}\Big/\frac{2g}{2\nu+1} = -q_\nu = -\tfrac{1}{2}(2\nu+1)\int_{-1}^{+1} dw f(w) Q'_\nu(w) \quad . \quad . \quad (29).$$

* See WHITTAKER'S *Modern Analysis*, ch. x., § 128.

In particular, the maximum disturbance of amplitude for the $\nu$-nodal seiche is given by

$$\partial k_\nu = \left| 2q_\nu \sin \frac{n_\nu \mathrm{T}}{2} \right| \quad . \quad . \quad . \quad . \quad . \quad . \quad (30).$$

It is of special interest to notice that the disturbance of the $\nu$-nodal seiche is due solely to the $\nu^{\text{th}}$ harmonic term in the zonal harmonic expansion of $f(w)$. It follows that a disturbance of pressure which is proportional to $\mathrm{Q}'_\nu(w)$ affects the $\nu$-nodal component of the lake oscillation and leaves all the others wholly unaltered.

6. *Example* 1.—Consider the effect of a uniform gradient of pressure suddenly generated over the whole length of the lake, and causing a difference $\partial p$ between the two ends. Such a disturbance will be represented by $\frac{1}{2}\partial p w$; *i.e.* by $q_1 \mathrm{Q}'_1(w)$, where $q_1 = \frac{1}{2}\partial p$. This will give $\partial k_2 = 0$, $\partial k_3 = 0$, etc., and

$$\partial k_1 = \left| \partial p \sin \left( \frac{n_1 \mathrm{T}}{2} \right) \right|,$$

if we suppose the uninodal seiche in such a phase when the disturbance commences that the maximum effect is produced.

The greatest effect of all results when $\mathrm{T} = \pi/n_1 = \frac{1}{2}\mathrm{T}_1$; *i.e.* when the disturbance lasts during half the uninodal period. We have then

$$\partial k_1 = \partial p .$$

It thus appears, as a result of our analysis, that a uniform pressure gradient established over the whole of a symmetric parabolic lake can only generate or destroy a pure uninodal seiche. If the oscillation of the lake have any other components, they are unaffected. This conclusion, which might have been expected *a priori*, seems to confirm the soundness of the assumptions on which we have based the present theory.

7. *Example* 2.—If we suppose the pressure disturbance given by $\frac{1}{2}\partial p(3w^2 - 1) = q_2 \mathrm{Q}'_2(w)$ $(q_2 = \partial p)$, which gives a parabolic distribution with a turning-point at the middle of the lake, and suppose the disturbance to catch the seiche in the most favourable phase, *i.e.* at a maximum, when the disturbing pressure tends to drive the water in the direction which it would follow if undisturbed, and if we further suppose the disturbance to last for half the binodal period, then we get

$$\partial k_2 = 2q_2 = 2\partial p$$

for the increase of the extreme amplitude of the binodal seiche, all the other seiche components being unaltered.

8. *Example* 3.—In like manner we see that the pressure disturbance which generates a pure trinodal seiche in a symmetric parabolic lake must have the cubic distribution $\frac{1}{2}q_3(5w^3 - 3w)$; and so on.

9. *Effect of a Disturbance of Pressure which varies both in Space and in Time.*—Let us suppose that the pressure, measured in centimetres of water, at time $t$, at any point $w(= x/a)$ of the parabolic lake, is given by

$$\partial p = f(w, t) \quad . \quad . \quad . \quad . \quad . \quad . \quad (31).$$

Availing ourselves of the principle of superposition, as heretofore, we can build up the general solution now required by adding together the contributions to $\zeta$ due to all the different elements of the lake-surface, and all the different elements of time at each element of surface.

Setting aside in the meantime the initial seiche motion, and calculating merely the part $d^2\zeta$ of $\zeta$ due to the disturbance of pressure, corresponding to $\mu \leqslant w \leqslant \mu + d\mu$ and $\mathrm{T} \leqslant t \leqslant \mathrm{T} + d\mathrm{T}$, we see at once from (23) and (24) that

$$d^2\zeta = \tfrac{1}{2}\Sigma(2\nu+1)Q'_\nu(w)Q'_\nu(\mu)n_\nu \sin n_\nu(\mathrm{T}-t)f(\mu, \mathrm{T})d\mu d\mathrm{T}.$$

If, therefore, we suppose the disturbance to last from $t=0$ to $t=\mathrm{T}$, we get, if $t \geqslant \mathrm{T}$, the following expression for the contribution to $\zeta$ due to the disturbance of pressure :

$$\partial\zeta = \tfrac{1}{2}\Sigma(2\nu+1)Q'_\nu(w)\int_{-1}^{+1} d\mu Q'_\nu(\mu)\int_0^{\mathrm{T}} d\mathrm{T} n_\nu \sin n_\nu(\mathrm{T}-t)f(\mu, \mathrm{T}) \quad . \quad . \quad . \quad (31).$$

This last equation will give the required disturbance in any particular case. We have merely to give the proper determination to the function $f(\mu, t)$ and carry out the two integrations. It may be noted that in general the integral $\int_0^{\mathrm{T}} d\mathrm{T} n_\nu \sin n_\nu(\mathrm{T}-t)f(\mu, \mathrm{T})$ will be a function of $\mu$.

If the pressure-disturbance have the form of a wave steady in shape and propagated with a uniform velocity $v$, then instead of $f(\mu, t)$ we may write the more specialised function $f\{a(1+w)-vt\}$.

10. *Special Case of a Sudden Rise of Pressure* $\partial$p, *propagated with uniform velocity* v, *starting at the negative end of the lake at* $\mathrm{t}=0$, *and ceasing all over the lake at* $\mathrm{t}=\mathrm{T}$.—First suppose $v\mathrm{T} > 2a$, so that every point of the lake is sooner or later affected. In this case, it is obvious that after T has reached the value $2a/v$, the disturbance contemplated has no longer any effect on the seiche motion, beyond an increase of the pressure everywhere by the amount $\partial p$. We may therefore suppose $\mathrm{T} = 2a/v$, and our formulæ will be applicable for $t \geqslant 2a/v$.

Since at any particular point $w=\mu$ the pressure is undisturbed until $t = a(1+\mu)/v$, and thereafter is raised by $\partial p$ until $t=\mathrm{T}$, the determination of $f(\mu, t)$ in this case is

$$f(\mu, t) = 0 \text{ for } t < a(1+\mu)/v;$$
$$f(\mu, t) = \partial p \text{ for } t \geqslant a(1+\mu)/v.$$

Hence (31) gives

$$\partial\zeta = \frac{\partial p}{2}\Sigma(2\nu+1)Q'_\nu(w)\int_{-1}^{+1} d\mu Q'_\nu(\mu)\int_{a(1+\mu)/v}^{\mathrm{T}} d\mathrm{T} n_\nu \sin n_\nu(\mathrm{T}-t),$$

$$= \frac{\partial p}{2}\Sigma(2\nu+1)Q'_\nu(w)\int_{-1}^{+1} d\mu Q'_\nu(\mu)[\cos n_\nu\{a(1+\mu)/v - t\} - \cos n_\nu(\mathrm{T}-t)].$$

Or, since $\int_{-1}^{+1} d\mu Q'_\nu(\mu) = 0$ in all cases,

$$\partial\zeta = \frac{\partial p}{2} \Sigma(2\nu+1)Q'_\nu(w) \int_{-1}^{+1} d\mu Q'_\nu(\mu) \cos n_\nu\{a(1+\mu)/v - t\} \quad . \quad . \quad . \quad (32).$$

If, therefore, we denote the $\nu$-nodal component of the disturbance by $\partial\zeta_\nu$, we have

$$\partial\zeta_\nu = (A'_\nu \cos n_\nu t + B'_\nu \sin n_\nu t)Q'_\nu(w) \quad . \quad . \quad . \quad . \quad (33),$$

where

$$\left.\begin{aligned} 2A'_\nu/(2\nu+1)\partial p &= \int_{-1}^{+1} d\mu Q'_\nu(\mu) \cos \frac{n_\nu a}{v}(1+\mu) \\ 2B'_\nu/(2\nu+1)\partial p &= \int_{-1}^{+1} d\mu Q'_\nu(\mu) \sin \frac{n_\nu a}{v}(1+\mu) \end{aligned}\right\} \quad . \quad . \quad . \quad (34).$$

Next suppose $v\mathrm{T} < 2a$. Then the pressure disturbance does not reach farther than $x = v\mathrm{T} - a$, that is $w = v\mathrm{T}/a - 1$; and we have

$$f(\mu, t) = 0, \text{ if } t > \mathrm{T}, \ \mu > v\mathrm{T}/a - 1;$$
$$f(\mu, t) = \partial p, \text{ if } a(1+\mu)/v \leqslant t \leqslant \mathrm{T}, \ -1 \leqslant \mu \leqslant v\mathrm{T}/a - 1.$$

Hence (31) now gives

$$\begin{aligned} \partial\zeta &= \frac{\partial p}{2} \Sigma(2\nu+1)Q'_\nu(w) \int_{-1}^{vT/a-1} d\mu Q'_\nu(\mu) \int_{a(1+\mu)/v}^{\mathrm{T}} d\mathrm{T} n_\nu \sin n_\nu(\mathrm{T}-t), \\ &= \frac{\partial p}{2} \Sigma(2\nu+1)Q'_\nu(w) \int_{-1}^{vT/a-1} d\mu Q'_\nu(\mu)[\cos\{a(1+\mu)/v - t\} - \cos n_\nu(\mathrm{T}-t)] \quad . \quad . \quad . \quad (32'). \end{aligned}$$

It follows that, if $t > \mathrm{T}$, then

$$\partial\zeta_\nu = (A'_\nu \cos n_\nu t + B'_\nu \sin n_\nu t)Q'_\nu(w) \quad . \quad . \quad . \quad . \quad (33'),$$

where now

$$\left.\begin{aligned} 2A'_\nu/(2\nu+1)\partial p &= \int_{-1}^{vT/a-1} d\mu Q'_\nu(\mu) \cos n_\nu \frac{a(1+\mu)}{v} - Q_\nu\left(\frac{v\mathrm{T}}{a} - 1\right) \cos n_\nu \mathrm{T}, \\ 2B'_\nu/(2\nu+1)\partial p &= \int_{-1}^{vT/a-1} d\mu Q'_\nu(\mu) \sin n_\nu \frac{a(1+\mu)}{v} - Q_\nu\left(\frac{v\mathrm{T}}{a} - 1\right) \sin n_\nu \mathrm{T} \end{aligned}\right\} \quad . \quad . \quad (34').$$

Superposing now the initial motion given by (6) and (8), we get for the $\nu$-nodal component of $\zeta$

$$\left.\begin{aligned} \zeta_\nu &= [\{k_\nu \cos n_\nu\tau_\nu + A'_\nu\} \cos n_\nu t + \{k_\nu \sin n_\nu\tau_\nu + B'_\nu\} \sin n_\nu t]Q'_\nu(w), \\ &= k'_\nu \cos n_\nu(t - \chi_\nu)Q'_\nu(w), \\ k'^2_\nu &= k_\nu^2 + 2k_\nu(A'_\nu \cos n_\nu\tau_\nu + B'_\nu \sin n_\nu\tau_\nu) + A'^2_\nu + B'^2_\nu; \\ \tan n_\nu\chi_\nu &= \frac{k_\nu \sin n_\nu\tau_\nu + B'_\nu}{k_\nu \cos n_\nu\tau_\nu + A'_\nu}; \\ \tan n_\nu(\chi_\nu - \tau_\nu) &= \frac{B'_\nu \cos n_\nu\tau_\nu - A'_\nu \sin n_\nu\tau_\nu}{k_\nu + A'_\nu \cos n_\nu\tau_\nu + B'_\nu \sin n_\nu\tau_\nu}. \end{aligned}\right\} \quad . \quad . \quad (35).$$

where

The values of $A'_\nu$ and $B'_\nu$ are given by (34) or (34'), according as $v\mathrm{T} >$ or $< 2a$.

If the square of $\partial p$ be negligible, so that $\partial k_\nu = k'_\nu - k_\nu$ and $\partial\tau_\nu = \chi_\nu - \tau_\nu$ are both small, we have

$$\left.\begin{aligned}\partial k_\nu &= \mathrm{A}'_\nu \cos n_\nu\tau_\nu + \mathrm{B}'_\nu \sin n_\nu\tau_\nu\\ \partial\tau_\nu &= (\mathrm{B}'_\nu \cos n_\nu\tau_\nu - \mathrm{A}'_\nu \sin n_\nu\tau_\nu)/k_\nu n_\nu\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (36).$$

The maximum value of $\partial k_\nu$ for different values of $\tau_\nu$ corresponds to $\tan n_\nu\tau_\nu = \mathrm{B}'_\nu/\mathrm{A}'_\nu$; and under these circumstances $\partial\tau_\nu = 0$, and $\partial k_\nu = (\mathrm{A}'^2_\nu + \mathrm{B}'^2_\nu)^{\frac{1}{2}}$.

11. As an example of the application of the above formulæ, let us consider the effect on the uninodal seiche of a sudden rise of pressure $\partial p$ which begins at the negative end of the lake at $t = 0$.

Putting $\mathrm{Q}'_1(\mu) = \mu$, and $\mathrm{Q}_1(\mu) = \frac{1}{2}(\mu^2 - 1)$, we get

$$\left.\begin{aligned}\mathrm{A}_1 &= -\tfrac{1}{2}(2\nu+1)\partial p\Theta,\\ \mathrm{B}_1 &= +\tfrac{1}{2}(2\nu+1)\partial p\Phi;\end{aligned}\right.$$

where, if $\theta = n_1 a/v = 2\pi a/v\mathrm{T}_1$,

$$\left.\begin{aligned}\Theta &= \frac{1-\cos 2\theta}{\theta^2} - \frac{\sin 2\theta}{\theta};\\ \Phi &= \frac{\sin 2\theta}{\theta^2} - \frac{1+\cos 2\theta}{\theta},\end{aligned}\right\} \text{ when } v\mathrm{T} > 2a:$$

and

$$\left.\begin{aligned}\Theta &= -\left\{\frac{1-\frac{1}{2}(n_1\mathrm{T})^2}{\theta^2} + \frac{n_1\mathrm{T}}{\theta}\right\}\cos n_1\mathrm{T} - \left\{\frac{n_1\mathrm{T}}{\theta^2} - \frac{1}{\theta}\right\}\sin n_1\mathrm{T} + \frac{1}{\theta^2};\\ \Phi &= \left\{\frac{1-\frac{1}{2}(n_1\mathrm{T})^2}{\theta^2} + \frac{n_1\mathrm{T}}{\theta}\right\}\sin n_1\mathrm{T} - \left\{\frac{n_1\mathrm{T}}{\theta^2} - \frac{1}{\theta}\right\}\cos n_1\mathrm{T} - \frac{1}{\theta},\end{aligned}\right\} \text{when } v\mathrm{T} < 2a. \quad . \quad (37).$$

It will be observed that in general $\Theta$ and $\Phi$ are functions of $v$ alone when $v\mathrm{T} > 2a$; but functions of $v$ and T when $v\mathrm{T} < 2a$.

If we restrict ourselves to the case where $\mathrm{T} = 2\pi/n_1 = \mathrm{T}_1$, then $n_1\mathrm{T}_1 = 2\pi$, and we get for the case where $v\mathrm{T}_1 < 2a$ [*i.e.* $v < 26{\cdot}9$ (mile/hour)]

$$\Theta = 2\left\{\left(\frac{\pi}{\theta}\right)^2 - \frac{\pi}{\theta}\right\};$$
$$\Phi = -\frac{2\pi}{\theta^2}.$$

In the case under consideration, therefore, the functions $\Theta$ and $\Phi$ are determined as follows:—

$$\left.\begin{aligned}\Theta &= \frac{1-\cos 2\theta}{\theta^2} - \frac{\sin 2\theta}{\theta} \text{ when } 0 \leqslant \theta \leqslant \pi;\\ &= 2\left\{\left(\frac{\pi}{\theta}\right)^2 - \frac{\pi}{\theta}\right\} \text{ when } \theta \geqslant \pi.\\ \Phi &= \frac{\sin 2\theta}{\theta^2} - \frac{1+\cos 2\theta}{\theta} \text{ when } 0 \leqslant \theta \leqslant \pi;\\ &= -\frac{2\pi}{\theta^2} \text{ when } \theta \geqslant \pi\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (38).$$

The graphs of $\Theta$ and $\Phi$ are given in figs. 21 and 22.

The greatest possible increase of amplitude is given by

$$\partial k_1 = \tfrac{3}{2}\partial p(\Theta^2 + \Phi^2)^{\frac{1}{2}}.$$

If $v\mathrm{T}_1 > 2a$, this leads to

$$\partial k_1 = 3\partial p\left(\frac{\sin\theta}{\theta^2} - \frac{\cos\theta}{\theta}\right) \quad (\theta < \pi) \qquad . \qquad . \qquad . \qquad . \qquad (39).$$

The graph of the function

$$\Psi = \frac{\sin\theta}{\theta^2} - \frac{\cos\theta}{\theta}$$

is shown in fig. 23.

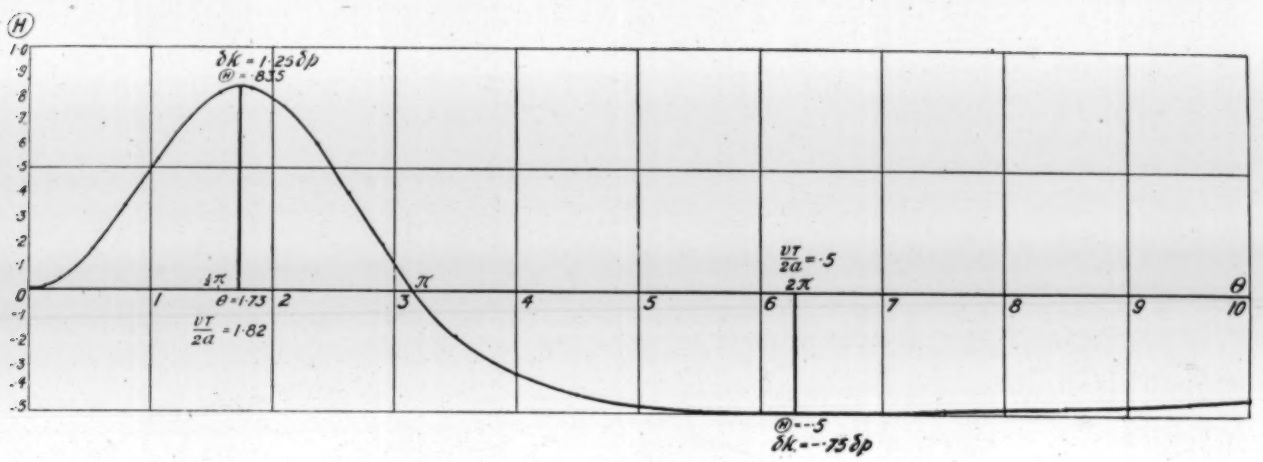



FIG. 21.

The maximum value of $\partial k_1$ is $1{\cdot}31\partial p$, corresponding to $v\mathrm{T}_1/2a = 1{\cdot}51$. Hence, since $\mathrm{T}_1 = 14{\cdot}5^{\mathrm{m}}$ and $2a = 6$ miles, the velocity of propagation of the pressure disturbance which has most effect on the uninodal seiche is about 37 (mile/hour).

If $v\mathrm{T}_1 < 2a$, then

$$\partial k_1 = 3\pi\partial p\left(\frac{\pi^2+1}{\theta^4} - \frac{2\pi}{\theta^3} + \frac{1}{\theta^2}\right)^{\frac{1}{2}} \quad (\theta > \pi) \qquad . \qquad . \qquad . \qquad . \qquad (40).$$

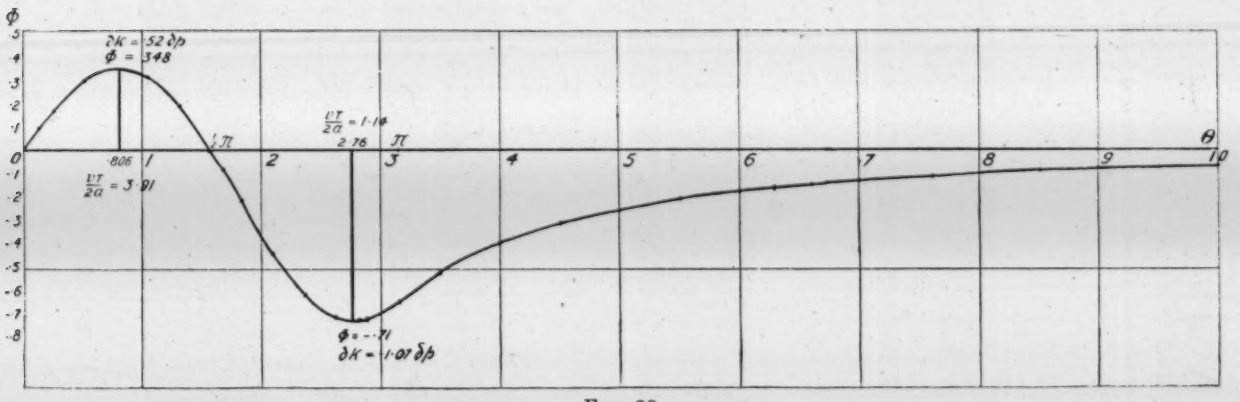



FIG. 22.

This has a minimum value when $\theta = 4{\cdot}0287$, and a maximum when $\theta = 5{\cdot}4061$.

Hence the maximum value of $\partial k_1$ is given by

$$\partial k_1 = 3\pi \times {\cdot}08234\partial p = {\cdot}776\partial p\,.$$

The corresponding velocity for the pressure disturbance is about 14 (mile/hour).

12. As a further example, we may take the case where $\mathrm{T} = \mathrm{T}_1$ as before, and we

suppose the pressure disturbance to reach the negative end of the lake just after the extreme amplitude there has reached a maximum; so that $\tau_1 = \pi/n_1$. In this case we have

$$\partial k_1 = -A_1' = \tfrac{3}{2}\Theta\partial p\,;$$
$$\partial \tau_1 = -B_1'/k_1 n_1 = -\tfrac{3}{2}\Phi\partial p/k_1 n_1\,.$$

In particular, the maximum increase of the extreme amplitude is $1{\cdot}253\partial p$, corresponding to $v\mathrm{T}_1/2a = 1{\cdot}82$. Since $\mathrm{T}_1 = 14{\cdot}5^{\mathrm{m}}$, this would give for the velocity of

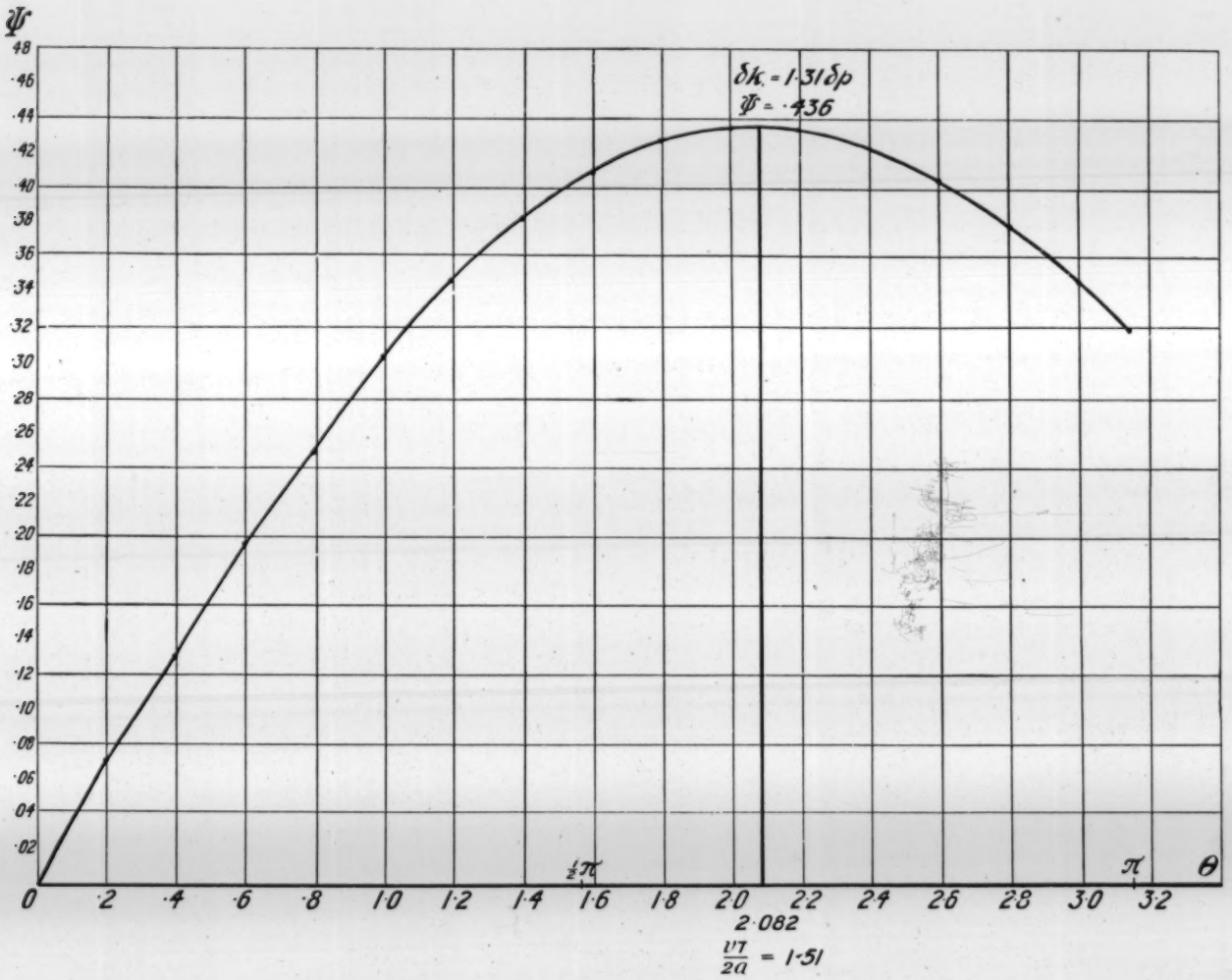



FIG. 23.

propagation of the pressure disturbance which produces the greatest effect about 45 (mile/hour).

If we put $\tau_1 = 0$, and suppose $v\mathrm{T}_1 < 2a$, we get

$$\partial k_1 = A_1' = -\tfrac{3}{2}\Theta\partial p\,;$$
$$\partial \tau_1 = B_1'/k_1 n_1 = \tfrac{3}{2}\Phi\partial p/k_1 n_1\,;$$

and the maximum value of $\partial k_1$ is $\cdot 75\partial p$, the corresponding value of $v$ being about 12 (mile/hour).

Again, if we take $T = T_1$ as before, but $\tau_1 = \frac{\pi}{2}$,

$$\partial k_1 = B_1' = \tfrac{3}{2}\Phi\partial p\,;$$
$$\partial\tau_1 = -A_1'/k_1n_1 = \tfrac{3}{2}\Theta\partial p/k_1n_1\,;$$

and the maximum value of $\partial k_1$ is $\cdot 52\partial p$, corresponding to $v = 97$ (mile/hour).

Lastly, for $T = T_1$, $\tau_1 = -\frac{\pi}{2}$,

$$\partial k_1 = -B_1' = -\tfrac{3}{2}\Phi\partial p\,;$$
$$\partial\tau_1 = A_1'/k_1n_1 = -\tfrac{3}{2}\Theta\partial p/k_1n_1\,;$$

and the maximum value of $\partial k_1$ is $\cdot 71\partial p$, corresponding to $v = 28$ (mile/hour).

## Alternative Method.

13. If the disturbance of phase is not required, the following method, by means of which I originally obtained some of the results given above, will furnish the disturbance of the extreme amplitudes of the various seiche components due to a given disturbance of pressure, to the same degree of approximation as Rayleigh's method.

If $K = \mathfrak{T} + \mathfrak{V}$ denote the whole energy of the seiche motion, $p$ the pressure at any point of the water surface, and $v_\nu$ the velocity of the water at that point in the direction of the normal to the surface drawn towards the water, then the following equation holds: *

$$\frac{DK}{Dt} = \int_{-a}^{a} dx p v_\nu = a\int_{-1}^{+1} dw p v_\nu .$$

It is easy to show that, for our purposes, the above equation may be written

$$\frac{DK}{Dt} = -a\int_{-1}^{+1} dw p\dot{\zeta} \quad . \quad . \quad . \quad . \quad . \quad (41);$$

for in so doing we neglect only quantities of the orders of $k_\nu^2/ha$ ($<1/10^8$) or $k_\nu^2/a^2$ ($<1/10^{10}$), already negligible if we are to apply the theory of long waves.

Suppose now the seiche motion to be analysed into uni-, bi-, tri-, . . . . nodal components whose amplitudes at the ends of the lake are $k_1$, $k_2$, $k_3$, . . . .

Since these components are normal modes of motion for the parabolic lake, we may calculate the total energies for each of these seiches separately and independently; and the sum of these energies will be K. Let these partial energies be $K_1$, $K_2$, $K_3$, . . . .

Taking the $\nu$-nodal seiche by itself, we have the equation

$$\frac{DK_\nu}{Dt} = -a\int_{-1}^{+1} dw p\dot{\zeta}_\nu \quad . \quad . \quad . \quad . \quad . \quad (42).$$

In the integral on the left-hand side of (42) we need pay no attention to any constant

* See Lamb's *Hydrodynamics*, 3rd ed. (1906), p. 9.

added to $p$, as the integral of a constant pressure all over the surface of the lake must obviously be zero. Hence we need only consider the disturbing pressure, which may be expressed in centimetres of water as heretofore by $\partial p = f(w, t)$.

If, therefore, $\partial \mathrm{K}_\nu$ denote the total increment of the energy of the $\nu$-nodal seiche by the disturbing pressure $\partial p = f(w, t)$ acting from $t = 0$ to $t = \Gamma$, we have

$$\partial \mathrm{K}_\nu = ag \int_{-1}^{+1} dw \mathrm{Q}'_\nu(w) \int_0^\Gamma dt\, k_\nu n_\nu \sin n_\nu (t - \tau_\nu) f(w, t) \quad . \quad . \quad . \quad (43).$$

The energy of the $\nu$-nodal seiche is equal to its potential energy in the configuration of maximum potential and zero kinetic energy. Hence we have by (11)

$$\mathrm{K}_\nu = \frac{ga}{2\nu + 1} k_\nu^2 \quad . \quad . \quad . \quad . \quad . \quad (44);$$

and therefore

$$\partial \mathrm{K}_\nu = \frac{2ga}{2\nu + 1} k_\nu \partial k_\nu \quad . \quad . \quad . \quad . \quad . \quad (45).$$

Strictly regarded, $k_\nu$ is a function of the time; for the energy of the seiche is being continually altered by the disturbing surface pressure, so that the extreme amplitude $k_\nu$ of the seiche at each moment, which would be left if the disturbing pressure were suddenly to cease, varies with the time. Inasmuch, however, as the variation of $k_\nu$ is small, and $f(w, t)$ is also small, if we neglect quantities of the order $\partial k_\nu \partial p$, we may regard $k_\nu$ as constant in the integral on the right-hand side of the equation (43).

We thus get from (43) and (45)

$$\partial k_\nu = \tfrac{1}{2}(2\nu + 1) \int_{-1}^{+1} dw \mathrm{Q}'_\nu(w) \int_0^\Gamma dt\, n_\nu \sin n_\nu (t - \tau_\nu) f(w, t) \quad . \quad . \quad . \quad (46),$$

a formula which summarises our whole theory so far as disturbance of the extreme amplitudes of the various seiches is concerned. It follows that

where

$$\left.\begin{aligned} \partial k_\nu &= \mathrm{A}'_\nu \cos n_\nu \tau_\nu + \mathrm{B}'_\nu \sin n_\nu \tau_\nu ; \\ \mathrm{A}'_\nu &= \tfrac{1}{2}(2\nu + 1) \int_{-1}^{+1} dw \mathrm{Q}'_\nu(w) \int_0^\Gamma dt\, n_\nu \sin n_\nu t \,.\, f(w, t) , \\ \mathrm{B}'_\nu &= -\tfrac{1}{2}(2\nu + 1) \int_{-1}^{+1} dw \mathrm{Q}'_\nu(w) \int_0^\Gamma dt\, n_\nu \cos n_\nu t \,.\, f(w, t) \end{aligned}\right\} \quad . \quad . \quad . \quad (47).$$

It will be found that the formulæ (47) lead to the same results, so far as amplitude is concerned, as we have already found in the special cases discussed above. We add some important examples of its application.

14. *Example* 1.—Let us consider the effect of a uniform time-change in a pressure gradient which has a uniform space variation along the lake. This will be represented by taking

$$f(w, t) = \tfrac{1}{2} atw ,$$

where $\alpha$ is the difference of pressure between the ends of the lake generated in unit of time.

Then we get from (46)

$$\partial k_\nu = \tfrac{1}{4}\alpha(2\nu+1)\int_{-1}^{+1} dw Q'_\nu(w) w \int_0^T dt\, n_\nu t \sin n_\nu(t-\tau_\nu)\,.$$

Since $w = Q_1'(w)$, and $\int_{-1}^{+1} dw Q'_\nu(w) Q_1'(w) = 0$, unless $\nu = 1$, in which case the value is $2/3$, it follows that a pressure disturbance of the kind under consideration can only generate a uninodal seiche in a symmetric parabolic lake; and we have, putting $n_1\tau_1 = \phi$ for shortness,

$$\partial k_1 = \tfrac{1}{2}\alpha(\mathrm{U}\cos\phi - \sin\phi)\,,$$

where

$$\mathrm{U} = \int_0^T dt\, n_1 t \sin n_1 t\,,$$
$$= \frac{1}{n_1}\{\sin\theta - \theta\cos\theta\}\,,$$

if $\theta = n_1 \mathrm{T}$; and

$$\mathrm{V} = \int_0^T dt\, n_1 t \cos n_1 t\,,$$
$$= \frac{1}{n_1}\{\theta\sin\theta - (1-\cos\theta)\}\,.$$

If we take the special case where the pressure disturbance begins when the uninodal seiche is at its culmination, $\phi = 0$; and we have

$$\partial k_1 = \frac{\alpha}{2n_1}(\sin\theta - \theta\cos\theta)\,.$$

It is easy to see that $\sin\theta - \theta\cos\theta$ has a maximum value when $\theta = \pi$, *i.e.* when $\mathrm{T} = \pi/n_1 = \tfrac{1}{2}\mathrm{T}_1$, as might be expected. The greatest possible disturbance under the present supposition regarding the phase would therefore be given by

$$\partial k_1 = \pi\alpha/2n_1 = \tfrac{1}{4}\alpha\mathrm{T}_1\,.$$

In other words, the alteration in the range of the seiche ($2\partial k_1$) would be equal to the number of millimetres (Aq.) of difference in pressure between the two ends of the lake generated in half the uninodal period.

If the initial phase be not given, but so chosen as to give the maximum effect to the disturbance, then

$$\partial k_1 = \frac{\alpha}{2n_1}\sqrt{(\mathrm{U}^2+\mathrm{V}^2)}\,,$$
$$= \frac{\alpha}{2n_1}\sqrt{(\theta^2 - 2\theta\sin\theta - \cos\theta + 2)}\,.$$

This has a maximum value when $\theta = 2\pi$, viz. :—

$$\partial k_1 = 2\pi\alpha/2n_1 = \tfrac{1}{2}\alpha\mathrm{T}_1\,.$$

15. *Example* 2.—Consider the effect of a steady (*i.e.* non-progressive) harmonic disturbance of pressure on the $\nu$-nodal seiche during a single period of that seiche.

If $a$ be the range of the pressure disturbance, we may put in (46)

$$f(w, t) = \tfrac{1}{2}a \sin (mt - \phi) f(w) \quad . \quad . \quad . \quad . \quad . \quad (48),$$

where $2\pi/m$ is the period of the pressure disturbance, and $\phi/m$ its phase. We then get, putting $\tau_\nu = 0$ for convenience,

$$\partial k_\nu = \tfrac{1}{4}(2\nu + 1)a \int_{-1}^{+1} dw Q'_\nu(w) \int_0^T dt\, n_\nu \sin n_\nu t \sin (mt - \phi) f(w) \quad . \quad . \quad . \quad (49),$$

where $T = 2\pi/n_\nu$.

Hence, if

$$P = \tfrac{1}{4}(2\nu + 1)a \int_{-1}^{+1} dw Q'_\nu(w) f(w), \quad . \quad . \quad . \quad . \quad (50),$$

a quantity independent of $t$ or T, we have

$$\left.\begin{aligned} \partial k_\nu / P &= U \cos \phi - V \sin \phi ; \\ U &= \int_0^T dt\, n_\nu \sin n_\nu t \sin mt , \\ V &= \int_0^T dt\, n_\nu \sin n_\nu t \cos mt \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (51).$$

where

If $\theta = m/n_\nu$, we find

$$\left.\begin{aligned} U &= -2 \sin \pi\theta \cos \pi\theta/(1 - \theta^2), \\ V &= 2 \sin \pi\theta \sin \pi\theta/(1 - \theta^2) \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (52).$$

Whence

$$\partial k_\nu = -P\left(\frac{2 \sin \pi\theta}{1 - \theta^2}\right) \cos (\pi\theta - \phi) \quad . \quad . \quad . \quad . \quad (53).$$

So far as $\phi$ is concerned, the numerical value of $\partial k_\nu$ is a maximum when $\phi = \pi\theta$, or $\phi = \pi(1 - \theta)$.

The maximum disturbance possible is therefore produced when $\theta$ is so chosen that $f(\theta) \equiv 2 \sin \pi\theta/(1 - \theta^2)$ is a maximum, *i.e.* when $\theta = \cdot 838$ approximately, which gives $f(\theta) = 3\cdot 273$. It will be seen, however, from the graph of $f(\theta)$ (fig. 24) that this function varies very slowly indeed near its maximum. We have in fact $f(\cdot 7) = 3\cdot 173$, $f(1) = \pi = 3\cdot 142$. Hence, between $\theta = \cdot 7$ and $\theta = 1$ the divergence from the maximum value of $f(\theta)$ is only about 4 per cent.*

If we take the special case of the uninodal seiche, and suppose $f(w) = w$, we find $P = \frac{1}{2}a$; and for the maximum possible value of $\partial k_1$

$$\partial k_1 = 1\cdot 18a ,$$

* This result may seem at first sight to be in contradiction with the ordinary theory of forced vibration; but it is not really so. In the ordinary theory we consider a practically infinite number of oscillations, and take into account the viscosity of the system. In the present case we consider only one oscillation, and neglect the viscosity. It is obvious that this latter supposition is nearer the truth in the case of lake oscillations, because the disturbances of pressure are always transient, and usually periodic only for a very few oscillations.

while the effect will not vary from this by more than 4 per cent., if the period of the pressure disturbance lies between $14{\cdot}5^{m}$ and $20{\cdot}6^{m}$.

Of course, in practice the maximum result is not usually attained, even if only one oscillation is considered, owing to divergence from the most effective phase of disturbance: also, if there are several periods of the disturbance, and $\theta$ is not unity, the effect produced during the first oscillation may not be equalled in those that follow, or may be partially destroyed.

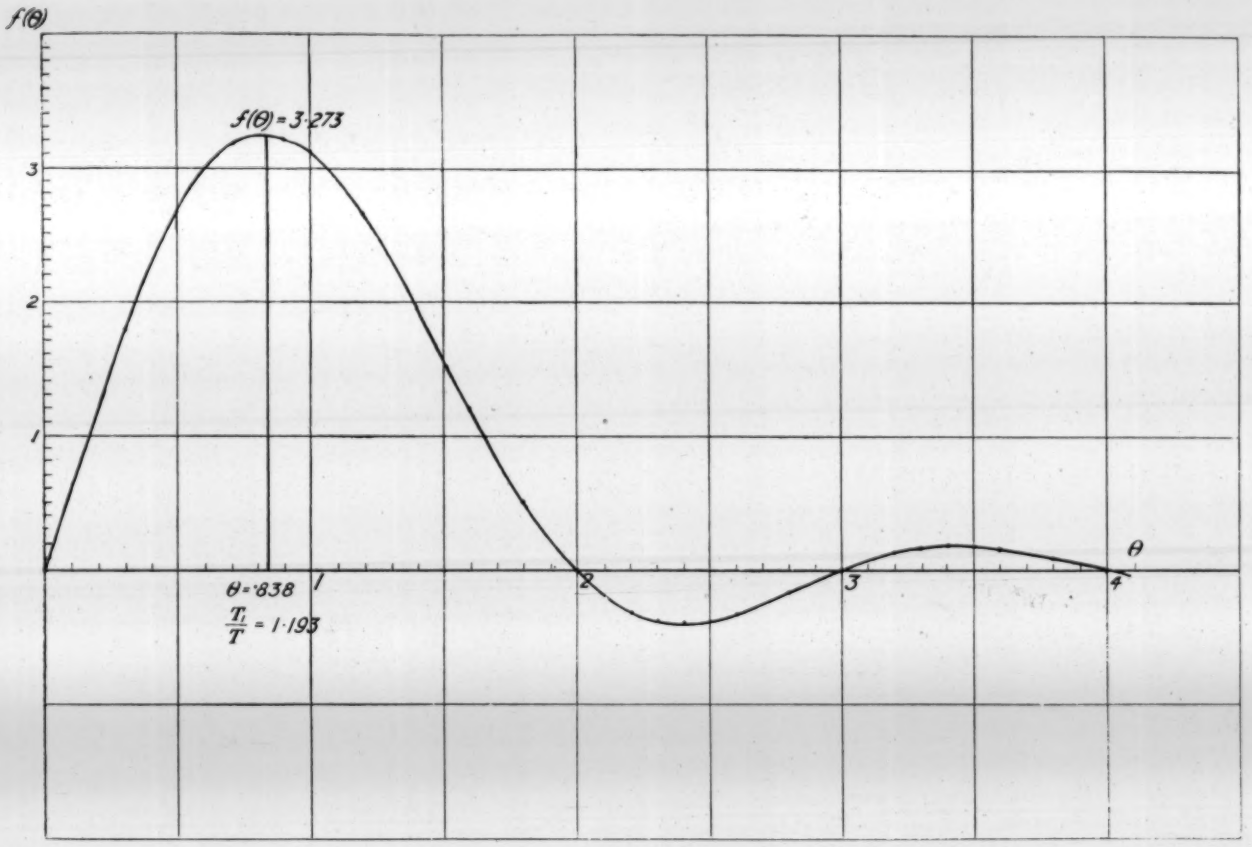



FIG. 24.

16. *Example* 3.—Consider the effect upon the uninodal seiche during one of its periods of a train of progressive harmonic waves of pressure disturbance given by

$$f(w, t) = \tfrac{1}{2}a \sin \left\{ \frac{m}{v}(vt - aw) - \phi \right\} \quad . \quad . \quad . \quad . \quad (54),$$

so that $2\pi/m$ is the period, and $v$ the velocity of propagation. Then we have

$$\partial k_1 = \tfrac{3}{4}a \int_{-1}^{+1} dw w \int_{0}^{T_1} dt n_1 \sin n_1 t \sin \{mt - \lambda w - \phi\},$$

where $\lambda = ma/v = 2\pi a/v\mathrm{T}$, T being the period of the disturbance.

Then

$$4\partial k_1/3a = \mathrm{U}\cos\phi - \mathrm{V}\sin\phi,$$

where

$$\left.\begin{aligned}\mathrm{U} &= \int_{-1}^{+1} dw\, w \int_0^{\mathrm{T}_1} dt\, n_1 \sin n_1 t \sin(mt - \lambda w),\\ \mathrm{V} &= \int_{-1}^{+1} dw\, w \int_0^{\mathrm{T}_1} dt\, n_1 \sin n_1 t \cos(mt - \lambda w)\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (55).$$

We find

$$\left.\begin{aligned}\mathrm{U} &= \left(-\frac{\sin\lambda}{\lambda^2} + \frac{\cos\lambda}{\lambda}\right)\frac{4\sin^2\pi\theta}{1-\theta^2},\\ \mathrm{V} &= \left(-\frac{\sin\lambda}{\lambda^2} + \frac{\cos\lambda}{\lambda}\right)\frac{4\sin\pi\theta\cos\pi\theta}{1-\theta^2}\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (56),$$

where $\theta = m/n_1 = \mathrm{T}_1/\mathrm{T}$.

Hence

$$\partial k_1 = -\tfrac{8}{2}a\left(\frac{\sin\lambda}{\lambda^2} - \frac{\cos\lambda}{\lambda}\right)\frac{2\sin\pi\theta}{1-\theta^2}\sin(\pi\theta - \phi) \quad . \quad . \quad . \quad (57).$$

The function $\sin\lambda/\lambda^2 - \cos\lambda/\lambda$ has already been considered above. Its maximum value (for $\theta < \pi$) is ·436. Also, as we have seen, the maximum value of $2\sin\pi\theta/(1-\theta^2)$ is 3·273.

Hence the maximum possible value of $\partial k_1$ is given approximately by

$$\partial k_1 = 2{\cdot}14a \quad . \quad . \quad . \quad . \quad . \quad . \quad (58).$$

The methods of calculation which we have used for a symmetric parabolic lake are, of course, applicable to any lake for which the normal modes of motion can be found. All we have to do is to use, instead of the Legendrian functions, the general Seiche functions, Bessel's functions, or other functions appropriate to the special form of lake-basin in question.

## CORRIGENDA IN PREVIOUS MEMOIRS.

"HYDRODYNAMICAL THEORY OF SEICHES," *Trans. R.S.E.*, vol. xli. p. 599.

| PAGE | LINE | |
|---|---|---|
| 603 | 23 | *Delete from* "which is the period" *to* "depth of water." |
| 616 | 19 | *For* $(+\partial\xi/\partial x)dy1$ *read* $(1+\partial\xi/\partial x)dy$. |
| 622 | 8 | *For* $n_2$ *read* $n_1$. |
| 634 | 9 | *For* $\frac{A}{a}$ *read* $\frac{A}{2a}$. |
| 636 | 9 & 12 | *For* $\frac{2a}{h}$ *read* $\frac{h}{2a}$. |
| 637 | 1 | *For* $\xi=\xi$ *read* $\xi=\xi'$. |
| ,, | 4 & 14 | *For* $\frac{2a^2}{h}$ *read* $\frac{h}{2}$. |
| ,, | 6 & 16 | *For* $\frac{2a'^2}{h}$ *read* $\frac{h}{2}$ |
| ,, | 8 & 9 | *Delete* $a^2$ *and* $a'^2$ |
| ,, | 9 | *For* $Y_1(na)$ *read* $Y_1(na)\}$. |
| ,, | 18 | *Delete* $a^2$ *and* $a'^2$. |
| 638 | 20, 22 / 31, 32 | *For* $\frac{2a}{h}$ *read* $\frac{h}{2a}$. |

"CALCULATION OF THE PERIODS AND NODES OF LOCH EARN," ETC., *Trans. R.S.E.*, vol. xli. p. 823.

| | | |
|---|---|---|
| 831 | 20 | *For* $c(1-1/1.2)\ldots.(1-1/(n-1)n)$ *read* $c(1-c/1.2)\ldots.(1-c/(n-1)n)$. |
| 833 | 14 | *For* $<\cdot000008$ *read* $<\cdot0000008$. |

"AN INVESTIGATION OF THE SEICHES," ETC, *Trans. R.S.E.*, vol. xlv. p. 361.

| | | |
|---|---|---|
| 385 | 25 | *For* $\left(t-a_1+\frac{T}{2}\right)$ *read* $\sin\frac{2\pi}{T_2}\left(t-a_2+\frac{T'_1}{4}\right)$. |

# XXI.—The Structure of Turrilepas Peachi and its Allies.

By **F. R. Cowper Reed**, M.A., F.G.S. *Communicated by* Dr Horne, F.R.S. (With a Plate.)

(MS. received July 18, 1908. Read July 20, 1908. Issued separately December 24, 1908.)

Having had the privilege of examining the type specimens of *Turrilepas scotica*, Etheridge jun.,* and *T. Peachi*, Etheridge jun. and Nicholson,† in Mrs Gray's collection, and in addition to them a large number of examples of the genus recently collected by Mrs Gray from the Girvan area, as well as many specimens in the Sedgwick Museum, Cambridge, from several horizons in the Haverfordwest district and from the Dufton Shales near Melmerby and from Bala beds of other localities, some important new features have been recognised in these curious fossils which help to throw light on their structure and relations.

Clarke‡ discussed in 1896 the relations of the genera *Turrilepas* (= *Plumulites*), *Lepidocoleus* and *Strobilepis*, but made no mention of these Scotch species of *Turrilepas* which differ in a marked way from *T. Wrightii* (De Koninck), which is the type of the genus. The latter species was described by Dr Henry Woodward in 1865,§ and is from the Wenlock beds of Dudley.

Ruedemann‖ has more recently given an account of the Trenton species, *Lepidocoleus Jamesi*, Hall and Whitfield, and has made some suggestive remarks on the associated narrow leaf-shaped plates.

In the case of the British examples of *Turrilepas* it is unfortunate that the specimens in nearly all cases consist of isolated plates, but amongst Mrs Gray's new material there is one nearly complete individual (Plate, fig. 1) from the Starfish bed with the plates in position, and it closely resembles the form described and figured by Barrande as *Plumulites folliculum* from Stage $Dd_2$. Though its state of preservation leaves something to be desired, yet it affords important evidence as to the relation of the separate plates and the general structure of the fossil, and indeed casts doubt on the view that *Plumulites*, Barrande, and *Turrilepas*, Woodward (type *T. Wrightii*) are synonymous.

Before proceeding to describe this specimen a few remarks may be made on the character and structure of the separate plates of *T. Peachi*, and on the specimens previously described by Etheridge and Nicholson. These authors described the kite-shaped plates as possessing a "strong, narrow median keel." From an examination of

* Etheridge jun., *Proc. R. Phys. Soc. Edin.*, 1878, iv. p. 166, pl. ii., figs. 1, 2; Etheridge and Nicholson, *Mon. Silur. Foss. Girvan*, fasc. ii., 1880, p. 214, pl. xiv., figs. 22–27.

† Etheridge and Nicholson, *Mon. Silur. Foss. Girvan*, fasc. iii., 1880, p. 301, pl. xx., figs. 8–10.

‡ Clarke, *Amer. Geol.*, xvii., 1896, pp. 137–143, pl. vii.

§ Woodward, *Quart. Journ. Geol. Soc.*, xxi., 1865, p. 486, pl. xiv., figs. 1*a*–1*l*.

‖ Ruedemann, *Bull. 49 New York State Mus.*, 1901, p. 87, pl. 4, figs. 16–19.

the type specimen* and other examples from the same horizon and locality, it is abundantly clear that this "keel" is really a narrow longitudinal sharp fold appearing on one side as a ridge or keel and on the other side as a groove. RUEDEMANN (*op. cit.*, pp. 88, 89) likewise has noticed that the apparent carina in *Lepidocoleus Jamesi* is the reverse side of a groove. In *T. Peachi* the groove, or rather fold, is on the outer side of the plate, and as it is the substance of the lamellated plate itself which is folded, the lamellæ are affected; there is not the least evidence of the presence of a median rod or anything resembling the main rib of a leaf such as ETHERIDGE and NICHOLSON indicated in their figures of *T. Peachi* and *T. scotica*, and described as a ridge-like keel. In both species the lamellæ which compose the plates are of regular and equal size, and the longitudinal fold which has been mistaken for a keel traverses them at right angles and is not strictly in the middle of the plate. Moreover, all of the kite-shaped plates in the type of *T. Peachi* show a narrower, less deeply impressed fold or groove above the main one, usually about half-way between it and the anterior margin, running similarly to the apex parallel to the edge of the plate. This groove is stronger in some detached plates than in the type. It should also be noticed that the lamellæ on the upper (anterior) half of the plates, *i.e.* above the median fold, do not curve forward so sharply or overlap to such an extent marginally as on the lower (posterior) half, but meet the upper margin nearly at right angles instead of at a very acute angle. This cannot be seen in the specimen figured by ETHERIDGE and NICHOLSON (*op. cit.*, fig. 8), as it is the inner surface of the series of plates which is exposed to view; for the plates themselves overlap from behind forwards in such a way that the anterior half of each plate lies above the posterior half of the preceding plate, so that the anterior portions of all the plates are consequently hidden in an inner view of the series. (Plate, fig. 4.)

*T. Peachi* is the only species from Girvan in which the plates have been found in natural serial position, and in the type specimen from Whitehouse Bay (Plate, fig. 4) there are five pairs of the kite-shaped plates present, though only those on the right side are well preserved. The longer axes of the plates in this specimen are inclined at about 75° to the axial line of the body of the fossil; in the other figured specimens (*op. cit.*, figs. 9, 10) the divergence of the lateral plates becomes progressively less towards the anterior end of the body, as ETHERIDGE and NICHOLSON remarked. The apical ends of these lateral plates are free, and in the type the surface of each plate seems not to be quite flat but to have weak broad longitudinal undulations, as well as the two sharp folds. In specimens such as this one, showing the true inner surface of the plates, the lamellæ are usually less obvious than on the outer surface. Portions of the thin calcareous shell are still adhering in many cases.

An important feature, not described or accurately figured by ETHERIDGE and NICHOLSON, is distinctly traceable in the oft-quoted type-specimen of *T. Peachi* here figured. This consists in the presence of a double median longitudinal row of strongly overlapping plates between the bases of the lateral kite-shaped plates. The plates of

* ETHERIDGE and NICHOLSON, *op. cit.*, pl. xx., fig. 8.

these two longitudinal rows are arranged in pairs and lie on the outer surface of the body, and therefore are partly hidden by the bases of the lateral plates in this inner view of the series. The bases of the median plates appear to lie on a level with the anterior narrow fold of the lateral plates, over which they extend laterally for one-fourth to one-third their length. The plates are of an oblique subtriangular shape with their apices directed forward, and they are in contact in the middle line by their inner edges. The base of each plate is broad, rounded and sinuous, being somewhat excavated in the middle, and thus divided into an outer broadly-rounded lobe and an inner subequal one, so far as can be seen. The inner basal angle is rounded and curves sharply forwards, so that the pairs of plates meet medianly in a series of acute angles. Owing to the strong overlapping of the successive plates in each longitudinal series the apices are not clearly seen; but judging from isolated plates and other specimens the shape of the plates was broad and short, with an apical angle of about 60°. The overlapping is of the same nature as that of the lateral plates, the posterior ones successively overlapping the anterior ones, so that in an inner view, as in the case of the type specimen (Plate, fig. 4), the apices are hidden. The surface of each plate is marked by regular equal lamellæ like the lateral plates, but they are concentric to the sinuous base, and there is no sharp narrow median fold, but a gentle, low, rounded submedian undulation traverses the plate longitudinally to the apex. The plates seem to be flattened and not markedly convex or angulated, though this appearance may be due to crushing of the specimen.

The specimens of *Turrilepas* from the Drummuck beds and Starfish bed of Thraive Glen (Plate, figs. 1–3*a*) seem to be specifically identical with those from Whitehouse Bay, and may be referred without much hesitation to *T. Peachi*. On one slab in Mrs GRAY's collection there are seven or eight of the kite-shaped plates associated, but not in natural serial position, and they show all the usual characters; two or three of the median plates in an imperfect condition occur along with them.

A very well-preserved isolated median plate from Thraive Glen (Plate, fig. 2) measures 6 mm. in length and nearly 7 mm. in breadth. The base is divided into two broad rounded lobes, of which the inner one is rather larger, and with the inner edge of the plate forms a continuous rounded curve. The outer edge (hypotenuse) is nearly straight, and slopes obliquely back from the apex, which has an angle of about 75°. A low submedian longitudinal fold traverses the length of the plate from the apex to the basal marginal sinus. The lamellæ on the outer half of the plate are rather wider apart and less crowded, as well as less sharply curved, than those on the inner half.

The most interesting specimen from the Upper Bala of Girvan is the nearly complete individual from the Starfish bed (Plate, fig. 1). This has all the lateral plates in position, and though their surface is poorly preserved and the median plates are only here and there fairly distinct, yet the whole structure and relation of the plates can be made out, and it is seen to resemble in a strikingly close manner the specimen represented by BARRANDE* as an adult example of *Plumulites folliculum* from Stage $Dd_2$. The posterior end of our

* BARRANDE, *Syst. Silur. Bohème*, suppl. vol. i., 1872, p. 573, pl. xx., fig. 15.

specimen is imperfect, but the general outline of the body is an elongated oval, with a very weakly convex surface, slightly carinated longitudinally down the middle. It is composed of a double series of overlapping plates, like the scales of a fir-cone, with their surface replaced by a film of yellow oxide of iron, just as BARRANDE described in his specimens, but where this has broken away we can see the transverse lamellæ of the plates, as in the typical examples of *Turrilepas*. The lateral plates composing the body are arranged in pairs in two longitudinal series on opposite sides of the median line, and their longer axes are inclined obliquely to this line, pointing forwards and making an angle of about 60° in the posterior part of the body, but the angle becomes increasingly more acute towards the anterior end till the last pair forming the apex make an angle of only 10°–15° and have their axes slightly curved inwards. The arrangement of the plates in pairs is rather obscured, owing to the poor preservation of the fossil, and it is impossible to determine the precise number, but there seem to be ten or eleven. Towards the anterior end they are more closely placed together, and overlap to a greater extent. The plates have the usual kite-shaped outline, but their margins are more or less broken, and they overlap in the usual way from behind forwards. They become rather narrower and more elongated in shape towards the anterior end of the body, and their apices are freer for a greater part of their length, while the more slender tapering shape of the last two or three pairs gives to them the appearance of spines. In all the posterior plates which are sufficiently preserved the usual submedian sharp fold is seen, but in the foremost two or three elongated plates there are in addition two very narrow submarginal folds, one on each side of the median line. The same feature is noticeable in some isolated plates from the same horizon and locality, and seems to characterise the terminal plates. The two rows of median plates can be traced only in places in this specimen and for the most part are obscure, but the general shape of the plates and their arrangement agree with what is seen in the Whitehouse Bay type-specimen.

The variation in the shape of the lateral plates is seen to be due to their different positions in the series composing the body; and probably some corresponding change occurs in the median series, as is suggested by isolated plates. The anterior lateral plates in the specimens of *T. Peachi* figured by ETHERIDGE and NICHOLSON (*op. cit.*, figs. 9, 10) are much less well preserved than the figures would lead us to infer, and no definite conclusions can be drawn from them, but they do not seem to be so attenuated as in the example from the Starfish bed (Plate, fig. 1). There is no evidence of the body being completely surrounded by plates, and the nature of the ventral side of the organism is unknown, but it may have been only membranous.

In consequence of the re-examination of the type-specimens of *T. Peachi* and the evidence afforded by the specimen from the Starfish bed, it appears that a certain amount of revision of ETHERIDGE and NICHOLSON's definition of the species is necessary; and in place of their summary of the specific characters the following may be substituted. It must still be somewhat incomplete, owing to the nature of the material available, but it marks a step forward in the comprehension of this peculiar organism.

*Definition.*—Body elongated oval, bilaterally symmetrical; dorsal side gently convex, subcarinate longitudinally, composed of two lateral series of large plates arranged in pairs and two median rows of small plates in contact in median line, and also in corresponding pairs. Shell thin, calcareous. Lateral plates kite-shaped, slightly curved, with pointed apex, but varying somewhat in shape according to their position, with their longer axes making nearly a right angle with the median carina of the body in the posterior part of the organism, but becoming less and less steeply inclined anteriorly till they lie nearly parallel at the anterior end. Surface of lateral plates marked by narrow submedian fold along their length and usually a narrower, less impressed one on their anterior half, both appearing as grooves on the outer surface and as ridges on the inner surface of the plates; [the most anterior pairs may have an anterior submarginal and a posterior submarginal narrow fold in addition to the submedian one, which is always the strongest]. Surface of plates crossed by regular transverse equal, closely placed and equidistant, imbricating lamellæ at right angles to main fold and meeting the anterior edge at a large angle, but curved forwards sharply towards the apex near the posterior edge of the plate and more closely crowded together. Apex of lateral plates more or less pointed and curved forwards; anterior edge slightly concave, posterior edge more or less convex; base broadly rounded, convex. Bases of opposite lateral plates nearly in contact. Successive plates overlap from behind forwards for about half their width, but their apices are free.

Median plates arranged in a double longitudinal series, with their inner edges in contact along carina of body. Shape of plates short, broad, subtriangular, with sinuated rounded base, long hypotenuse, more or less arched perpendicular; apices directed forwards and overlapping considerably from behind forwards. Surface of plates marked by one or two low submedian longitudinal folds from apex to base and by regular equal transverse imbricating lamellæ concentric to base, meeting hypotenuse at large angle but curving forward sharply at inner angle concentrically to inner edge of plate and more closely crowded together. Terminal plate single, subcircular, emarginate. (See Addenda.)

Specimens of kite-shaped plates from the Sholeshook Limestone and Redhill Shales of the Haverfordwest area seem indistinguishable from Girvan examples of *T. Peachi*, and probably it is the same species which occurs in the Staurocephalus Limestone and Ashgill Shales of the Lake District. The genus is also represented, perhaps by the same species, in the St Martin's beds of the neighbourhood of Haverfordwest.

With regard to *T. scotica* only isolated plates are known, but they belong to both the lateral kite-shaped series and to the median triangular rows. No associated series in position is yet known. Etheridge and Nicholson mention only Balclatchie as the locality at which this species is found, but it occurs in the same beds at Ardmillan and Dow Hill, and Mrs Gray has many excellent examples of it from the latter place. In the specimens of the lateral plates figured by Etheridge and Nicholson (*op. cit.*, pl. xiv., figs. 22, 23, 24) the weak narrow fold between the median one and the anterior margin of the plate is not so strongly marked as in *T. Peachi*, but in one specimen from

Dow Hill there are present the two narrow submarginal folds, one on each side of the median one close to the edges (Plate, fig. 7), as in the complete individual of *T. Peachi* from the Starfish bed.

The slender attenuated apex of the kite-shaped plates (Plate, fig. 12) and the broader, more rapidly tapering form of the plates, is a more or less marked distinction from *T. Peachi*; the curvature of the plates depends on what part of the series they come from, and cannot be considered a constant or reliable specific difference, but the lamellæ are more numerous and closer together than in *T. Peachi* and meet the anterior margin at nearly a right angle, while they curve forwards sharply towards the apex on the posterior margin of the plate (Plate, figs. 9, 11, 12).

The isolated triangular plates which may be referred to the median series (*e.g.* ETHERIDGE and NICHOLSON, *op. cit.*, pl. xiv., fig. 26) are much like those of *T. Peachi*, but usually have a more distinct and broader rounded longitudinal groove on each side of the rounded median fold or undulation (Plate, fig. 8).

The plate with the rounded apical end figured by ETHERIDGE and NICHOLSON from Balclatchie (*op. cit.*, pl. xiv., fig. 27) is also represented amongst Mrs GRAY'S specimens from Dow Hill (Plate, fig. 10), and as the pointed kite-shaped ones have been shown to belong to the anterior end of the body in *T. Peachi*, it is probable that this rounded plate belongs to the posterior end. It must be regarded as one of the kite-shaped, lateral series on account of its median sharp fold, though its apex has been modified. As ETHERIDGE and NICHOLSON pointed out (p. 215), such a plate with an obtuse apex was called by BARRANDE (*op. cit.*, p. 567) the "Valve fenestrée" (="cancellated plate"), but they did not remark that this plate from Balclatchie differs from all the other plates of *T. scotica* by being bilaterally symmetrical. The median fold in it is truly placed in the middle; it ends abruptly in the subcircular depression round which the lamellæ curve. The lamellæ are parallel to each other and at right angles to the median fold, and curve forward very slightly (but to an equal extent on each side near the margin), while at the front end they sweep round in a circle and unite around the depression at the end of the median fold. Until a complete individual is found the true relation of this plate to the others cannot be determined. The same may be said of the strongly convex small triangular plate, such as ETHERIDGE and NICHOLSON figured on pl. xiv., fig. 25. This plate (Plate, fig. 13) has a thick calcareous shell preserved, and the whole surface is strongly bent down on each side of the median line; it is asymmetrically triangular, and if flattened would be referred to the left row of the double median series. It is difficult to realise its relation to the rest of the plates on the body, as they all seem to be more or less flattened. In shape and convexity it much resembles the plates of the type of the genus, *T. Wrightii*, from the Wenlock. As the similarly shaped plates of *Turrilepas* from the *Orthis argentea* zone of Haverfordwest and from the Dufton Shales have an intermediate convexity, it seems likely that the much flattened condition of the plates is largely due to the thinness of the shell or to crushing, or to both combined. It should be mentioned also that in this convex specimen from Balclatchie

the lamellæ are not curved forward near the margins, but meet them nearly at right angles, and the base also is not sinuated. Probably the difference in the shape of the plate and the want of curvature in the lamellæ is connected with its position in the median series; or it may be the case that in *T. scotica* part of the axial line of the body is more strongly carinated and the plates therefore more strongly folded, or they may overlap in the middle line.

A large triangular convex plate from Dow Hill (Plate, fig. 6) resembles this strongly folded plate in some respects, but it is much larger than any others referable to *T. scotica*, and differs in certain ways from the type. It measures 14 mm. long and 10 mm. wide at the base; it is irregularly triangular in shape, with the axial line somewhat curved and the apex bent inwards to the shorter inner side; the surface is strongly convex, the plate being folded sharply along a slightly curved line nearer the inner than the outer border; the inner slope is short, steep, and slightly excavated, but the outer one is gently inclined, gently convex, and more than twice as wide as the inner face, and has a very shallow longitudinal median depression running back from the apex to the weak sinus in the base of this face. The whole base of the plate is angulated at the fold, the inner part sharply curving forward at about 45° and passing into the inner margin of the plate, while the outer part of the base slopes forward obliquely with a sinuous outline at about 75° to the ridge, and has a broadly rounded outer angle. The lamellæ, which cross without interruption the whole surface of the plate, are numerous, parallel and equal, but are more closely crowded on the inner face and concentric to the inner margin, while on the outer face they are less closely placed, are concentric to the sinuated base, and meet the outer edge at about 60°.

Probably this plate belongs to the median series of the body, but it can only be doubtfully referred to *T. scotica*.

The only other representatives of *Turrilepas* which I have seen from the Girvan district come from the Middle Llandovery of Newlands. The small imperfect isolated kite-shaped plates and fragmentary median plates are too poor for description or identification with any described species.

The species of *Turrilepas* from the *Orthis argentea* zone of Haverfordwest is only known to me by median plates, which, however, are rather numerous in Prendergast Lane and are well preserved. They are short, broad, and irregularly triangular, with an apical angle of 60° to 75°; they are as broad as long, and are divided by a broad rounded or angulated fold into very unequal halves; the inner face is steeply inclined and narrow, the outer face is flattened and nearly three times as wide. The base is slightly sinuated, and the lamellæ, which are closely placed, meet the outer edge nearly at right angles. From numerous internal casts it is seen that the interior of these plates has a smooth surface. No kite-shaped plates from these beds have come under my notice.

The species of *Turrilepas* from the Dufton Shales of Melmerby is represented mostly by small, short, broad, triangular plates of the median series, but a few imperfect kite-

shaped plates have been found. The material is too imperfect for specific description, but the form seems allied to *T. scotica.*

From the above description of fairly perfect specimens of *Turrilepas Peachi* from Girvan it seems legitimate to doubt if this and its allied species are congeneric with *T. Wrightii*, if we strictly adhere to Dr WOODWARD's original description of the type. Clarke has remarked on the want of definiteness in our knowledge of the latter, but the specimen of *T. Wrightii* seems to be referable to the peduncular part of the barnacle. The question arises whether we are to regard the fossils mainly built up of the kite-shaped plates as the capitular portion of the same genus. The structure as now revealed does not seem to commend this theory, and though one may be unwilling to go back to the old idea of the fossil belonging to the polyplacophorous molluscs, yet it is difficult to maintain its reference to *Turrilepas* in its strict sense. On the other hand, it seems to bear a considerable resemblance to the genus *Strobilepis* of CLARKE* from the Hamilton Group of New York, which is described as having four vertical rows of plates, *i.e.* two lateral rows of large plates symmetrically disposed and an intermediate ventral and dorsal single series; the ventral series consists of spines. Our forms differ by having a double instead of a single dorsal series, and the ventral surface is unknown; but otherwise there are some striking points of similarity in the regular arrangement of the plates and the symmetrical shape of the fossil as seen in a dorsal view, and CLARKE is not quite satisfied as to the true position of the ventral row of spines.

With regard to foreign species referable to the same genus as *T. Peachi* and *T. scotica*, it may be mentioned that the plate described under the name of *T. canadensis*, WOODWARD,† from the Utica States of Canada, bears a close resemblance to the form from the *Orthis argentea* beds of Haverfordwest. *T. Mitchelli*, Etheridge jun.,‡ from the Wenlock beds of New South Wales, is known by kite-shaped, "cancellated," and median plates, according to the published figures, but ETHERIDGE thinks the median plate represents another species. The several allied Bohemian species, described by BARRANDE as *Plumulites*, are referred to by ETHERIDGE and NICHOLSON in their accounts of the Girvan species, and there is no need to discuss them again here.

The latest known species, stratigraphically, which have been described are those from the Hamilton Group of New York.§ Most of them are founded on isolated plates which possess either the shape of the median plates of *T. Peachi* and *T. scotica* or the so-called "cancellated plates" of the latter; no typical kite-shaped plates have been described. The conical, strongly folded plate of *T.* (?) *Newberryi* (CLARKE, *op. cit.*, p. 219, pl. xxxvi., fig. 16) much resembles the figured one referred by ETHERIDGE and NICHOLSON to *T. scotica* (ETHERIDGE and NICHOLSON, *op. cit.*, pl. xiv., fig. 25) which has been discussed above; and CLARKE remarks how widely this differs from the plates

* CLARKE, *Palæont. New York*, vol. vii., 1888, p. 212, pl. xxxvi., figs. 20–22; *Amer. Geologist*, xvii., 1896, p. 138, pl. vii., figs. 11, 12.

† WOODWARD, *Geol. Mag.*, Dec. iii., vol. vi., 1889, p. 274, woodcut.

‡ ETHERIDGE jun., *Geol. Mag.*, Dec. iii., vol. vii., 1890, p. 337, pl. xi., figs. 1–5.

§ CLARKE, *Palæont. New York*, vol. vii., 1888, pp. 215–220, pl. xxxvi., figs. 1–19.

termed *Plumulites* by BARRANDE and from the other New York species, and expresses his difficulty in understanding how "the combination of these sub-conical bodies in vertical ranges could produce such a scaly peduncle or capitulum as existed in *Turrilepas.*" But *T. Wrightii*, the type of the genus, consists of such plates. Consequently, it is obvious that much uncertainty exists as to the true reference and relations of such isolated plates, and it has not been lessened by the suggestion that some properly belong to Cystideans. We must wait for further and better material before we can hope to clear up all the difficulties connected with these curious organisms, but it is felt that with regard to *T. Peachi* and *T. scotica* we have now made some advance in the knowledge of their structure, however much it may affect our views as to their generic reference and zoological affinities.

## ADDENDA.

Since the above was written, two specimens have been sent me by Mrs GRAY, which probably represent the single terminal plates of the paired median series of plates in both *T. scotica* and *T. Peachi.* The specimen from Balclatchie (Plate, fig. 14) shows a small subcircular flattened plate with a shallow median notch in its posterior (?) margin, lying near the end of a somewhat disarranged series of the usual triangular plates attributed to the median series of *T. scotica.* The other, from Whitehouse Bay (Plate, fig. 15), is a plate of similar shape, but rather more emarginate and with stronger concentric striation and possessing a group of 3–4 rugæ radiating from the centre to the margin opposite the notch; it may probably belong to *T. Peachi.* Another example of the latter species from the same locality, having the anterior part of the body preserved, shows that the arrangement and shape of the lateral plates at this end is the same as in the figured specimen (Plate, fig. 1) from the Starfish bed. In connection with the occurrence of the genus as defined by WOODWARD, it should have been mentioned that AURIVILLIUS has recorded it from the Silurian of Gotland (*Bihang till K. Svenska Vet. Akad. Handl.*, Bd. 18, iv., No. 3, 1892, p. 20). The genus has also been recognised by the present author amongst some Silurian fossils recently collected in the Northern Shan States, Burma, by the Geological Survey of India.

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## EXPLANATION OF PLATE.

Fig. 1. *Turrilepas Peachi*, Eth. jun. and Nich. Nearly complete individual (slightly restored). × 4. Starfish bed.

„ 1*a*. „ „ „ „ Transverse section of same specimen.

„ 2. „ „ „ „ Median plate. × 2. Thraive Glen.

„ 3. „ „ „ „ Lateral plate, inner surface. × 3. Starfish bed.

„ 3*a*. „ „ „ „ „ outer surface. × 4. Starfish bed.

„ 4. „ „ „ „ Inner surface of portion of body, showing lateral and median plates (figured by ETH. jun. and NICH., *Mon. Silur. Foss. Girvan*, pl. XX., fig. 8). × 5. Whitehouse Bay.

„ 5. „ „ „ „ Median plate. × 3. Whitehouse Bay.

Fig. 6. *Turrilepas* sp. Carinated median (?) plate. × 2. Dow Hill.
„ 7. *Turrilepas scotica*, Eth. jun. Lateral plate. × 6. Dow Hill.
„ 8. „ „ „ Median plate. × 4. Dow Hill.
„ 9. „ „ „ Lateral plate, outer surface. × 6. Dow Hill.
„ 9*a*. „ „ „ „ „ reverse of same specimen. × 6.
„ 10. „ „ „ "Cancellated plate." × 6. Dow Hill.
„ 11. „ „ „ Lateral plate, outer surface (figured by Eth. and Nich., *op. cit.*, pl. xiv., fig. 23). × 6. Balclatchie.
„ 12. „ „ „ Lateral plate, inner surface (figured by Eth. and Nich., *op. cit.*, pl. xiv., fig. 22). × 6. Balclatchie.
„ 13. „ „ „ Median (?) plate (figured by Eth. and Nich., *op. cit.*, pl. xiv., fig. 25). × 5. Balclatchie.
„ 14. „ „ „ Median plates with supposed single terminal plate. × 3. Balclatchie.
„ 14*a*. „ „ „ Same terminal plate. × 8.
„ 15. *Turrilepas Peachi*, Eth. jun. and Nich. Supposed single terminal plate. × 3. Whitehouse Bay.

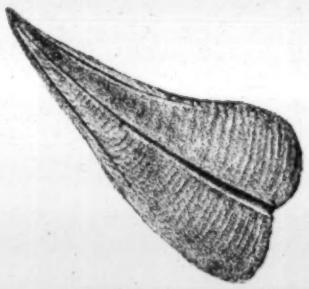
1a. x 4

2. x 2

1. x 4

5. x 3

3. x 3



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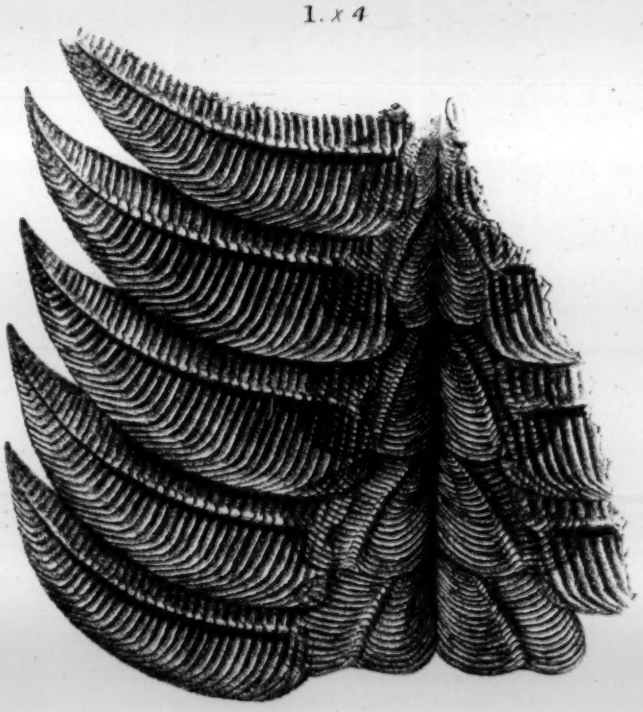

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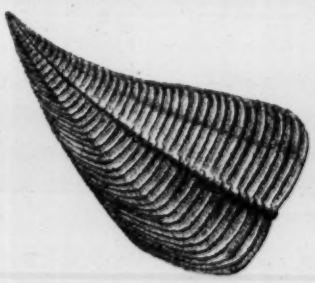

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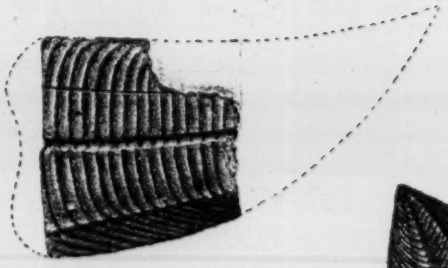

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# XXII.—Astéries, Ophiures et Échinides de l'Expédition Antarctique Nationale Écossaise.

Par le Dr. **R. Koehler**, Professeur de Zoologie à l'Université de Lyon. *Présentée par le* Dr. W. S. Bruce. (Avec seize Planches.)

(MS. received September 5, 1907. Read June 15, 1908. Issued separately December 16, 1908.)

La collection d'Astéries, d'Ophiures et d'Échinides, dont M. le Dr. William S. Bruce a bien voulu me confier l'étude, comprend surtout les échantillons recueillis par l'Expédition de la *Scotia* lors de son séjour dans l'Antarctique et quelques autres provenant des îles Falkland, du banc de Burdwood et de l'île Gough, ou de dragages effectués entre le 46° et le 51° lat. S. M. Bruce y a joint quelques spécimens capturés pendant le voyage de retour de la *Scotia*, au Cap, à Sainte-Hélène, à l'Ascension et à Saint-Vincent.

Afin de ne point mélanger des espèces de provenances aussi différentes, j'ai cru devoir diviser mon mémoire descriptif en deux parties : l'une, à beaucoup près la plus étendue, comprend les formes antarctiques et subantarctiques rapportées par la *Scotia*, et qui sont nouvelles pour la plus grande partie ; l'autre renfermera les espèces rencontrées pendant le voyage de retour de la *Scotia* et qui, à l'exception de deux, avaient déjà été observées ; mais parmi ces dernières quelques unes étaient insuffisamment connues et elles mériteront une description spéciale.

Ayant déjà eu l'occasion d'examiner les Échinodermes de l'Expédition de la *Belgica* et de l'Expédition Charcot, j'ai accepté avec le plus grand plaisir l'offre que M. Bruce a bien voulu me faire, d'étudier les Astéries, les Ophiures et les Échinides rapportés par la *Scotia*. Je le remercie très vivement de la confiance qu'il m'a témoignée et lui suis infiniment reconnaissant d'avoir mis à ma disposition la collection d'Échinodermes antarctiques la plus importante qui ait été recueillie jusqu'à ce jour.

Je remercie également tous mes collègues qui m'ont aidé dans l'accomplissement de mon travail. J'adresse tout particulièrement mes remerciements et l'expression de ma vive gratitude à mon excellent ami, M. le Dr. Mortensen, qui m'a fait profiter, de la manière la plus aimable, de sa grande connaissance des Échinides et a bien voulu revoir plusieurs de mes espèces.

M. le Professeur van Beneden, M. le Professeur Joubin et M. le Dr. Steinhauss, ont bien voulu m'envoyer en communication plusieurs échantillons d'Échinodermes qui m'ont grandement facilité mes déterminations : je leur suis extrêmement reconnaissant de leur grande obligeance et les prie de recevoir mes plus sincères remerciements.

## PREMIÈRE PARTIE.

### Astéries, Ophiures et Échinides, recueillis par la *Scotia* dans les régions Antarctiques.

Un certain nombre d'Échinodermes ont été capturés aux îles Falkland et sur le banc de Burdwood, c'est à dire au dessous du 50° lat. S. ; les autres proviennent de latitudes beaucoup plus élevées, comprises entre le 60° et le 72° lat. S. Enfin quelques échantillons ont été rapportés de l'île Gough, au Sud de Tristan d'Acunha, et que les cartes françaises désignent sous le nom de Diégo Alvarez.

Les navigateurs qui ont exploré les régions australes de notre globe s'accordent généralement à faire commencer l'Antarctique à la limite de la banquise. Cette limite varie suivant la longitude : ainsi dans un point du détroit du Drake, elle ne dépasse pas le 60° lat. S., puis elle se relève progressivement à la hauteur du Cap Horn et des îles Falkland, et coupe alors le 55° lat. S. en laissant au Nord le banc de Burdwood. A la hauteur de la Géorgie du Sud, cette limite se rapproche du 50°, qu'elle peut même atteindre plus à l'est. Il est commode d'adopter, pour la géographie zoologique, cette même limite de la région antarctique.

Quant à la région subantarctique qui fait suite à la précédente, et qui se relie à elle par de nombreuses espèces communes, ses limites au Nord sont plus difficiles à préciser car elles paraissent subir des inflexions qui correspondent peut-être à celles qu'offre la même région au Sud ; de plus, nous manquons souvent de renseignements exacts sur la faune de beaucoup de régions australes. La Terre de Feu, les îles Falkland et le banc de Burdwood, explorés par la *Scotia*, appartiennent incontestablement à cette région, et il est très vraisemblable que dans le Sud de l'Amérique, ses limites doivent être voisines du 50°, peut-être un plus au Nord. Dans l'Océan Indien, cette limite doit aussi passer au Nord du 50°, de manière à comprendre dans la région subantarctique les îles Marion, Crozet, Kerguelen, etc.

Quant à l'île Gough, à laquelle la *Scotia* a touché lors de son retour et où elle a rencontré quelques espèces que j'étudie dans la première partie de ce travail, elle se trouve placée à l'extrême limite septentrionale de la région subantarctique. Sa faune échinologique comprend une association curieuse que voici :

*Crossaster penicillatus*, Sladen.
*Cribrella Pagenstecheri*, Studer.
*Amphiura magellanica*, Ljungmann.
„ *squamata* (Delle Chiaje).
*Ophiacantha Valenciennesi*, Lyman.
*Ophiomitrella ingrata*, nov. sp.
*Notechinus magellanicus*, var. *neu-amsterdami*, Döderlein.

Parmi ces espèces, l'*Ophiacantha Valenciennesi* et l'*Amphiura squamata* sont cosmopolites ; le *Crossaster penicillatus* n'était connu qu'à Tristan d'Acunha et la variété *neu-amsterdami* du *Notechinus magellanicus* a été rencontrée à l'île Amsterdam. D'autre part, la *Cribrella Pagenstecheri* et l'*Amphiura magellanica* étaient connues dans le détroit de Magellan. L'*Ophiomitrella ingrata*, espèce nouvelle, ne peut intervenir dans cette comparaison.

Pendant son séjour dans l'Antarctique, la *Scotia* a effectué de nombreux dragages à de grandes profondeurs : c'est le premier bateau qui ait fait autant de dragages abyssaux à ces hautes latitudes australes. Dans les pages qui suivent, je décrirai plusieurs espèces qui ont été capturées à des profondeurs variant de 1410 à 2645 brasses. Il n'est pas surprenant que des espèces provenant de ces parages absolument inexplorés soient presque toutes nouvelles.

Avant de passer à l'étude des espèces, il me parait utile d'en faire une énumération préalable, en séparant les formes de profondeur et les formes littorales et en indiquant les stations.

## Astéries.

Trente-cinq espèces ont été recueillies en tout : vingt sont des formes de profondeur et quinze sont littorales.

Les formes de profondeur sont les suivantes :—

| | Lat. S. | Long. W. | Profondeur en brasses. |
|---|---|---|---|
| *Dytaster felix*, nov. sp. | 71° 22′ | 16° 34′ | 1410 |
| *Psilasteropsis facetus*, nov. sp. | 48 6 | 10 5 | 1742 |
| *Ripaster Charcoti*, Koehler | 62 10 | 41 20 | 1775 |
| *Odontaster pusillus*, nov. sp. | 48 6 | 10 5 | 1742 |
| *Chitonaster Johannæ*, nov. sp. | 62 10 | 41 20 | 1775 |
| *Marcelaster antarcticus*, nov. gen., nov. sp. | 62 10 | 41 20 | 1775 |
| *Ganeria attenuata*, nov. sp. | 62 10 | 41 20 | 1775 |
| *Scotiaster inornatus*, nov. gen., nov. sp. | 51 7 | 9 31 | 2103 |
| *Hymenaster campanulatus*, nov. sp. | 71 22 | 16 34 | 1410 |
| „ *edax*, nov. sp. | 62 10 | 41 20 | 1775 |
| „ *fucatus*, nov. sp. | 71 22 | 16 34 | 1410 |
| „ *densus*, nov. sp. | 69 33 | 15 19 | 2620 |
| *Lophaster abbreviatus*, nov. sp. | 62 10 | 41 20 | 1775 |
| *Solaster Lorioli*, nov. sp. | 67 33 | 36 35 | 2500 |
| *Styracaster robustus*, nov. sp. | 51 7 | 9 31 | 2103 |
| *Hyphalaster Scotiæ*, nov. sp. | 71 22 | 16 34 | 1410 |
| *Zoroaster tenuis*, Sladen | 48 6 | 10 5 | 1742 |
| *Asterias pedicellaris*, nov. sp. | 71 22 | 16 34 | 1410 |
| *Freyella Giardi*, nov. sp. | 67 33 | 36 35 | 2500 |
| | 69 33 | 15 19 | 2620 |
| *Belgicella racovitzana*, Ludwig | 71 22 | 16 34 | 1410 |

Sur ces vingt espèces, trois seulement étaient connues : ce sont les *Ripaster Charcoti*, *Belgicella racovitzana* et *Odontaster tenuis*. Les deux premières provenaient des régions antarctiques, mais le *Ripaster Charcoti* n'y avait encore été rencontré que dans des stations littorales. La *Belgicella racovitzana* a été draguée par la *Belgica* à 2800 mètres ; quant au *Zoroaster tenuis*, le *Challenger* l'a découvert par 2° lat. S. et 144° long. W., à une profondeur de 1070 brasses.

Parmi les espèces nouvelles, treize proviennent de régions absolument antarctiques et ont été draguées entre le 62° et le 71° lat. S. Le *Scotiaster inornatus* et le *Styracaster robustus* ont été rencontrés par 51°, le *Psilasteropsis facetus* et l'*Odontaster pusillus* par 48° lat. S. Toutes ces formes proviennent de profondeurs comprises entre 1410 et 2620 brasses. Deux de ces espèces forment les types des genres nouveaux *Marcelaster* et *Scotiaster*.

Les formes littorales sont les suivantes :

| | Localités. | Profondeurs en brasses. |
|---|---|---|
| *Odontaster Grayi*, J. Bell | Banc de Burdwood | 56 |
| ,, *validus*, Koehler | Orcades du Sud | 5–10 |
| *Retaster verrucosus*, Sladen | Banc de Burdwood | 56 |
| *Cycethra verrucosa* (Philippi) | Banc de Burdwood | 56 |
| | Iles Falkland | 5–20 |
| *Cribrella Pagenstecheri*, Studer | Banc de Burdwood | 56 |
| | Ile Gough | 25 |
| *Solaster australis* (Perrier) | Banc de Burdwood | 56 |
| *Crossaster penicillatus*, Sladen | Ile Gough | 25 |
| *Granaster biseriatus*, Koehler | Orcades du Sud | 0–5 |
| *Anasterias cupulifera*, nov. sp. | Orcades du Sud | 10 |
| ,, *tenera*, Koehler | Orcades du Sud | 0–20 |
| *Stolasterias Brucei*, nov. sp. | Orcades du Sud | 10 |
| *Diplasterias Turqueti*, Koehler | Orcades du Sud | 10–20 |
| ,, *Brandti*, J. Bell | Iles Falkland | 5–20 |
| | Banc de Burdwood | 56 |
| ,, *induta*, nov. sp. | Orcades du Sud | 10–20 |
| *Asterias antarctica*, Lütken | Iles Falkland | 0–6 |

Sur ces quinze espèces, trois sont nouvelles. Ce sont :

*Stolasterias Brucei.*
*Anasterias cupulifera.*
*Diplasterias induta.*

Les autres espèces ont été à peu près toutes trouvées dans des parages voisins de ceux où elles avaient déjà été rencontrées. A part le *Crossaster penicillatus* que la *Scotia* a rapporté de l'île Gough, et qui avait été découvert par le *Challenger* à Tristan d'Acunha, toutes les autres espèces proviennent des îles Falkland, des Orcades du Sud et du banc de Burdwood. La *Cribrella Pagenstecheri* a été rencontrée à la fois

au banc de Burdwood et à l'île Gough : cette forme, ainsi que je le dirai plus loin, appartient sans doute à une espèce très polymorphe et répandue dans toutes les régions subantarctiques.

Il est très vraisemblable qu'un certain nombre des espèces d'Astéries qui viennent d'être citées peuvent se trouver indifféremment dans des stations littorales et dans des stations abyssales, ainsi que nous l'observons déjà pour les *Ripaster Charcoti* et *Belgicella racovitzana*.

## Ophiures.

Le nombre total des Ophiures recueillies par la *Scotia* s'élève à trente et un. Dix-neuf proviennent de grandes profondeurs. Ce sont :

| | Lat. S. | Long. W. | Profondeur en brasses. |
|---|---|---|---|
| *Ophioglypha Brucei*, nov. sp. | 66° 40′ | 40° 35′ | 2425 |
| „ *integra*, nov. sp. | 62 10 | 41 20 | 1775 |
| „ *lenticularis*, nov. sp. | 51 7 | 9 31 | 2103 |
| „ *figurata*, nov. sp. | 62 10 | 41 20 | 1775 |
| „ *ossiculata*, nov. sp. | 71 22 | 16 34 | 1410 |
| „ *mimaria*, nov. sp. | 71 22 | 16 34 | 1410 |
| „ *anceps*, nov. sp. | 71 22 | 16 34 | 1410 |
| „ *scissa*, nov. sp. | 71 22 | 16 34 | 1410 |
| „ *partita*, nov. sp. | 62 10 | 41 20 | 1775 |
| „ *inops*, nov. sp. | 71 22 | 16 34 | 1410 |
| „ *bullata*, Wyville Thomson | 39 48 | 2 33 | 2645 |
| *Ophiocten Ludwigi*, nov. sp. | 62 10 | 41 20 | 1775 |
| *Ophiernus quadrispinus*, Koehler | 62 10 | 41 20 | 1775 |
| *Amphiura magnifica*, nov. sp. | 51 7 | 9 31 | 2103 |
| „ *consors*, nov. sp. | 69 33 | 15 19 | 2620 |
| *Ophiacantha frigida*, nov. sp. | 62 10 | 41 20 | 1775 |
| „ *opulenta*, nov. sp. | 62 10 | 41 20 | 1775 |
| „ *cosmica*, Lyman | 66 40 | 40 35 | 2425 |
| | 39 48 | 2 33 E. | 2645 |
| *Ophiotrema Alberti*, Koehler | 51 7 | 9 31 W. | 2103 |

De ces espèces, trois seulement étaient connues. Ce sont :

*Ophioglypha bullata.*
*Ophiacantha cosmica.*
*Ophiotrema Alberti.*

L'*Ophioglypha bullata* a déjà été trouvée dans l'Atlantique Sud par le *Challenger* et elle est connue dans plusieurs stations de l'Atlantique Nord : elle parait être cosmopolite dans les grands fonds. Il en est de même de l'*Ophiacantha cosmica*, rencontrée dans le Sud des Océans Indien et Atlantique et dans le Pacifique équatorial. Quant à l'*Ophiotrema Alberti*, elle n'était encore connue que dans l'Atlantique Nord.

La richesse des *Ophioglypha* est particulièrement remarquable dans les fonds visités par la *Scotia*, et sur seize espèces nouvelles rapportées, ce genre en renferme dix à lui seul.

Les Ophiures littorales appartiennent à douze espèces, qui sont :

| | Localités. | Profondeurs en brasses. |
|---|---|---|
| *Amphilepis antarctica*, nov. sp. | Orcades du Sud | 9–10 |
| *Ophiactis asperula* (Philippi), | Banc de Burdwood | 56 |
| *Amphiura Mortenseni*, nov. sp. | Orcades du Sud | 9–10 |
| „ *tomentosa*, Lyman | Orcades du Sud | 9–10 |
| „ *magellanica*, Lyman | Ile Gough | 75 |
| „ *squamata* (Delle Chiaje) | Ile Gough | 75 |
| *Ophiacantha vivipara*, Ljungmann | Banc de Burdwood | 56 |
| „ *Valenciennesi*, Lyman | Ile Gough | 100 |
| *Ophiomitrella ingrata*, nov. sp. | Ile Gough | 100 |
| *Ophiomyxa vivipara*, Studer | Banc de Burdwood | 56 |
| *Astrotoma Agassizi*, Lyman | Banc de Burdwood | 56 |
| *Gorgonocephalus chilensis* (Philippi) | Banc de Burdwood | 56 |

Trois de ces espèces seulement sont nouvelles. Parmi les autres, deux sont cosmopolites : ce sont les *Amphiura squamata* et *Ophiacantha Valenciennesi*. L'*Amphiura magellanica*, trouvée à l'île Gough, était connue au détroit de Magellan. Quant à l'*Amphiura tomentosa*, elle n'a encore été rencontrée qu'à Kerguelen, et les exemplaires trouvés par la *Scotia* ne sont pas tout à fait conformes au type, dont ils représentent peut-être une variété. Les autres espèces sont subantarctiques.

## Échinides.

Les Échinides sont moins nombreux et ne comprennent que dix espèces en tout. Quatre seulement sont abyssales ; ce sont :

| | Lat. S. | Long. W. | Profondeur en brasses. |
|---|---|---|---|
| *Stereocidaris Mortenseni* (Koehler) | 71° 22′ | 16° 34′ | 1410 |
| *Pourtalesia carinata*, Agassiz | 66 40 | 40 35 | 2425 |
| | 69 33 | 15 19 | 2620 |
| *Delopatagus Brucei*, nov. gen., nov. sp. | 66 40 | 40 35 | 2425 |
| *Urechinus fragilis*, nov. sp. | 71 22 | 16 34 | 1410 |

Les deux dernières espèces sont nouvelles et l'une forme le type d'un genre nouveau. Le *Stereocidaris Mortenseni* a déjà été rencontré par la *Belgica* entre le 70° et le 71°

lat. S., mais à une profondeur beaucoup plus faible (de 100 à 600 mètres). La *Pourtalesia carinata* a été draguée par le *Challenger* dans plusieurs stations australes des Océans Indien et Pacifique.

Les espèces littorales sont au nombre de six :

| | Localités. | Profondeur en brasses. |
|---|---|---|
| *Stereocidaris canaliculata* (Agassiz) . . | Iles Falkland . . . . . | 0–5 |
| *Sterechinus margaritaceus* (Agassiz) . . | Banc de Burdwood . . . . | 56 |
| „ *Neumayeri* (Meissner) . . . | Orcades du Sud . . . . . | 6–10 |
| *Notechinus magellanicus*, var. *neu-amsterdami*, Döderlein . . . . . | Ile Gough . . . . . | 100 |
| *Hemiaster cavernosus* (Philippi) . . . | Orcades du Sud . . . . . | 6–10 |
| „ *elongatus*, nov. sp. . . . | Orcades du Sud . . . . . | 6–10 |

Toutes ces espèces, sauf la dernière qui est nouvelle, ont déjà été rencontrées dans des parages voisins de ceux où la *Scotia* les a recueillies. La variété *neu-amsterdami* du *Notechinus magellanicus* provient de l'île Amsterdam, qui se trouve sur la même latitude que l'île Gough.

Il me parait absolument inutile de reprendre ici la comparaison des faunes échinologiques arctique et antarctique pour montrer, une fois de plus, en s'appuyant sur les documents fournis par les explorations de la *Scotia*, que ces faunes sont complètement différentes l'une de l'autre ; la question est jugée depuis longtemps. Mais il est un autre fait qui résulte de cette comparaison, et qui me parait hors de conteste, c'est que la faune antarctique est plus riche que la faune arctique ; j'ajouterai qu'elle est aussi moins uniforme. Elle est plus riche, car le nombre des espèces antarctiques actuellement connues est plus élevé que le nombre des espèces arctiques. Or tandis que les régions boréales ont été l'objet de nombreuses explorations et que les espèces nouvelles y deviennent de plus en plus rares, les régions antarctiques, au contraire, commencent à peine à être explorées et ont déjà fourni un nombre important d'espèces qui s'accroîtra vraisemblablement avec les futures explorations. On connait, en effet, l'uniformité de la faune arctique, qui s'explique facilement par la continuité des continents dans la région boréale : cette continuité contraste avec l'état isolé des terres australes. Autant qu'on en peut juger actuellement, les faunes de la Patagonie, de Kerguelen et de la Nouvelle-Zélande sont assez différentes. Or on n'a guère exploré jusqu'à maintenant, dans l'Antarctique, que la partie située au sud du Cap Horn, et il est permis de croire que les recherches qui pourront être effectuées dans l'avenir, sous d'autres longitudes, feront connaître d'autres formes encore.

## ASTÉRIES.

*Dytaster felix*, nov. sp. (Pl. I. fig. 1 à 3.)

18 Mars 1904, 71° 22′ lat. S., 16° 34′ long. W. ; profondeur 1410 brasses. Deux échantillons.

Dans le grand exemplaire $R = 72$ et $r = 14$ millim. Cet exemplaire n'est pas en très bon état ; quatre bras sont cassés vers l'extrémité et le disque est plus ou moins endommagé. Le petit exemplaire est mieux conservé ; ses dimensions sont : $R = 40$ millim., $r = 10$ millim.

Le disque est assez grand ; les bras sont plutôt étroits à la base, où leur largeur atteint 18 à 20 millim. : ils vont en s'amincissant graduellement jusqu'à l'extrémité, qui est fine et pointue. La face dorsale est couverte de paxilles très serrées, un peu inégales et irrégulièrement arrondies. Elles sont très petites, surtout dans la région centrale du disque, et les plus grandes ne dépassent pas 0·7 à 0·8 millim. Elles présentent quelques granules centraux, au nombre de deux à six, entourés d'un cercle de granules périphériques plus petits. En général, un des granules, ou même parfois deux, se relèvent sur les paxilles de la région centrale du disque, en un petit piquant court, arrondi à l'extrémité et couché. La disposition des paxilles devient un peu plus régulière dans le voisinage des angles interradiaux, où elles offrent une tendance à se disposer en rangées parallèles. La plaque madréporique est très grande, ovalaire, allongée dans le sens radiaire : son bord externe est éloigné de cinq millim. environ des plaques marginales dorsales.

Sur les bras, les paxilles médianes sont disposées sans ordre et ne diffèrent pas de celles du disque. Les paxilles latérales forment de petites rangées transversales assez régulières, renfermant chacune six à sept paxilles. Ces paxilles latérales, quoique plus petites que les médianes, ont presque toutes leur granule central, qui est unique, relevé en un petit cône mousse, tandis que sur le milieu du bras, les paxilles, qui sont un peu plus grandes et qui possèdent plusieurs granules centraux, n'en offrent pas qui soient ainsi relevés.

L'aire paxillaire des bras est très large et les plaques marginales dorsales sont comparativement très étroites. Celles-ci sont un peu plus larges que longues, mais quand on les regarde par en haut, la partie qui apparait à la face dorsale des bras se montre un peu plus longue que large. Elles sont bien séparées les unes des autres, ainsi que des marginales ventrales qui leur correspondent exactement. Elles sont couvertes de granules serrés, arrondis, devenant simplement un peu plus petits vers les bords : il n'existe jamais de rangée marginale se distinguant des autres granules, soit par la taille, soit par la régularité.

Les plaques latéro-ventrales couvrent un espace assez étroit. Les rangées qu'elles forment ne sont pas faciles à distinguer sur le grand échantillon en raison des piquants et des pédicellaires qu'elles portent. Sur le petit exemplaire, ces rangées sont mieux définies et la première rangée interradiale renferme six plaques. Toutes les plaques portent des piquants courts, coniques, serrés, assez gros sur la face ventrale même de la plaque, devenant plus petits et plus fins et s'inclinant obliquement sur les côtés. La plupart de ces plaques offrent un groupe de trois piquants transformés en un gros pédicellaire tridactyle, dont les valves sont épaisses, allongées et parfois arquées. Ces pédicellaires sont très apparents et je les retrouve sur le petit exemplaire. Ils se continuent sur les bras et je les observe encore en face de la dixième plaque marginale ventrale.

Les plaques marginales ventrales, petites, correspondent aux dorsales. Elles sont un peu plus larges que longues dans l'angle interbrachial, puis elles deviennent à peu près aussi larges que longues. Elles sont couvertes de granules serrés et un peu allongés. Dans l'angle interbrachial, l'un de ces granules se relève, vers le milieu de la face externe de la plaque, en un petit piquant conique, à pointe émoussée, qui se rapproche progressivement du bord distal de la plaque. Toutes les plaques n'offrent pas ce piquant et je ne l'aperçois pas au delà de la moitié du bras : peut-être cette absence est-elle accidentelle. Au dessus de ce piquant et vers le bord supérieur de la plaque, c'est à dire vers l'intervalle qui la sépare de la plaque marginale dorsale correspondante, j'observe souvent, et surtout au commencement du bras, un pédicellaire tridactyle, identique à celui des plaques ventrales. Ces pédicellaires se montrent aussi sur le petit échantillon.

Les tubes ambulacraires sont contractés, avec une ventouse terminale très petite. Le sillon n'est pas très large, sauf vers le milieu du bras.

Les plaques adambulacraires offrent, dans le sillon, une première rangée de piquants allongés, au nombre de huit à dix par plaque et disposés régulièrement en forme de peigne, les médians un peu plus longs que les autres. En dehors, viennent deux rangées irrégulières de piquants plus grands et plus gros, au nombre de trois à six par rangée : ces piquants sont lancéolés et pointus. Quelques plaques adambulacraires portent également un pédicellaire.

Les dents présentent, sur leurs bords, des piquants nombreux et très serrés qui s'allongent en dedans. Sur leur face ventrale, on remarque une rangée externe de petits granules et en dedans deux rangées irrégulières de granules.

*Rapports et Différences.*—Le *D. felix* s'écarte de tous les *Dytaster* connus : il est surtout remarquable par le nombre des pédicellaires de la face ventrale et par la présence de ces pédicellaires sur le bord dorsal des plaques marginales ventrales ainsi que sur les plaques adambulacraires. Par sa forme générale, c'est avec le *D. nobilis* Sladen que le *D. felix* a le plus d'analogie, mais il s'en distingue par l'absence de piquants sur les plaques marginales dorsales et par ses pédicellaires.

*Psilasteropsis facetus*, nov. sp. (Pl. II., fig. 16 à 18.)

13 Avril 1904, 48° 6′ lat. S., 10° 5′ long. W. ; profondeur 1742 brasses. Deux échantillons.

Dans le plus grand individu, $R = 93$ et $r = 22$ millim. ; dans l'autre, $R = 75$ et $r = 20$ millim.

Ces échantillons sont malheureusement en assez mauvais état : dans le plus grand, dont deux bras seulement sont cassés vers l'extrémité, la face dorsale n'est pas trop détériorée, mais les plaques marginales dorsales ont perdu leur revêtement ; quant à la face ventrale, elle a beaucoup souffert, et la plupart des piquants des plaques ventrales, des plaques marginales, des dents et des plaques adambulacraires ont été arrachés. L'autre individu a les bras cassés et la face dorsale est très endommagée, tandis que la face ventrale est, du moins en certains endroits, moins détériorée que sur le grand individu.

Le disque est grand et même comparativement plus développé dans le petit échantillon. Les bras sont forts et épais, assez larges à la base, et ils vont en s'amincissant très régulièrement jusqu'à l'extrémité, qui est très pointue. La face dorsale est plane et la face ventrale convexe ; les faces latérales du disque et des bras sont hautes et verticales.

La face dorsale du disque est couverte de paxilles extrêmement petites et serrées dans la région centrale où elles sont irrégulièrement disposées ; leur diamètre n'est que de 0·2 à 0·3 millim, puis elles deviennent rapidement plus grandes et se disposent en files radiaires régulières. Sur les bras, on observe une bande médiane de paxilles très petites qui continuent les petites paxilles centrales et forment cinq ou six rangées longitudinales irrégulières ; de chaque côté de cette bande, partent des rangées transversales obliques et bien régulières de paxilles plus grandes, au nombre d'une dizaine par rangée à la base des bras. C'est surtout dans les intervalles de ces rangées que se trouvent les papules. Au microscope, ces paxilles se montrent constituées par des spinules dressées verticalement, comprenant un groupe central en nombre variable, entouré d'un cercle périphérique de mêmes dimensions. La plaque madréporique est très petite ; elle est située plus près du bord que du centre. Il existe un très petit anus central entouré par quelques cercles de paxilles extrêmement réduites.

Les plaques marginales dorsales, au nombre d'une quarantaine, sont larges, épaisses et proéminentes ; leur face externe est convexe. Ces plaques sont très hautes et elles forment à peu près les deux tiers de la hauteur des bras ; elles sont séparées par des sillons très marqués. Elles sont couvertes de granules assez gros, larges et aplatis, qui deviennent brusquement plus petits vers le bord sutural : on observe ainsi trois ou quatre rangées de ces granules plus petits et la plaque voisine présente des rangées analogues, mais jamais ces granules ne s'allongent et ils n'offrent aucune tendance à

former des pédicellaires fasciolaires. Vers le milieu de son bord externe, chaque plaque offre un piquant allongé, aplati et pointu ; on peut même parfois en observer deux superposés dans l'arc interbrachial, mais en général ces piquants sont arrachés : ils manquent presque tous dans le grand échantillon et sont mieux conservés dans le petit.

Les plaques marginales ventrales, qui correspondent aux dorsales, sont aussi larges mais moins hautes que ces dernières. Elles sont couvertes de granules aplatis et serrés et offrent, en outre, une rangée de piquants assez larges, forts, aplatis et pointus, en forme de lame de sabre et couchés sur la plaque. Dans l'arc interbrachial, on compte quatre ou cinq piquants sur chaque plaque ; ce nombre tombe ensuite à trois. Le piquant interne est le plus petit et la longueur augmente jusqu'au plus externe qui égale presque l'article. Vers les bords suturaux, les granules deviennent plus petits et offrent la même disposition que sur les plaques dorsales.

Les plaques latérales ventrales forment des séries transversales allant des adambulacraires aux marginales ventrales : la première rangée interradiale renferme six plaques, puis le nombre diminue rapidement. Il y a environ une dizaine de séries, dont les dernières n'ont que deux plaques et finalement une seule plaque. Ces plaques sont garnies de piquants très courts, dressés, serrés, à extrémité arrondie et qui ressemblent plutôt à des granules allongés.

Les sillons ambulacraires sont larges. Les tubes ambulacraires sont gros, pointus, avec une ventouse rudimentaire. Il est à peu près impossible de reconnaître les caractères des piquants adambulacraires en raison de l'état des échantillons. J'observe une rangée interne, au nombre de six à huit piquants environ et formant un peigne dressé ; en dehors viennent deux rangées ventrales plus ou moins régulières, mais je ne puis distinguer ni le nombre, ni la disposition exacte des piquants.

L'armature des dents est également enlevée en grande partie. Je distingue cependant sur le bord libre de chaque dent une rangée de piquants forts, dressés, très serrés les uns contre les autres. Sur la face ventrale, il semble n'y avoir qu'une seule rangée de piquants très courts, formant plutôt de gros granules aplatis et disposés parallèlement à la rangée externe.

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*Rapports et Différences.*—J'ai placé cette Astérie dans le genre *Psilasteropsis* parce qu'elle offre une grande ressemblance extérieure avec le *Ps. patagiatus* (Sladen), mais elle diffère de cette espèce, comme du *Ps. cingulata* W. K. Fisher, par la présence de piquants sur les plaques marginales dorsales. A ce point de vue, le *Ps. facetus* se rapproche du *Ps. humilis*, que j'ai décrit récemment et chez lequel les plaques marginales dorsales aussi sont armées. Une détermination générique précise ne pourrait être faite qu'à la condition de pouvoir observer les caractères des dents et des piquants adambulacraires, ce que je n'ai malheureusement pas pu faire. Notre Astérie rappelle aussi les *Persephonaster* : ce genre est d'ailleurs extrêmement voisin du genre *Psilasteropsis*.

*Ripaster Charcoti*, Koehler.

KOEHLER, *Expédition Antarctique française du Dr. Charcot: Echinodermes*, p. 4, pl. iii., fig. 20, 21, 31 et 32.

18 Mars 1903, 62° 10′ lat. S., 41° 20′ long. W.; profondeur 1775 brasses. Trois échantillons.

Ces échantillons sont dans un état déplorable : le disque et les bras sont repliés, cassés, déformés, dénudés et ces débris sont à peine reconnaissables. Ils appartiennent évidemment au genre *Ripaster* tel que je l'ai défini et je ne puis les distinguer du *Ripaster Charcoti*, qui peut ainsi descendre à une profondeur beaucoup plus grande que celle où le *Français* l'a recueilli.

*Odontaster validus*, Koehler.

KOEHLER, *Expédition Antarctique française du Dr. Charcot: Echinodermes*, p. 6, pl. iii., fig. 22–26.

Mars–Novembre 1903, Baie de la Scotia, Orcades du Sud; profondeur 5–10 brasses. Quelques échantillons.

Juin 1903, Orcades du Sud; profondeur 9–10 brasses. Trois échantillons, dont deux à quatre bras.

31 Janvier 1904, îles Falkland; profondeur 5–20 brasses. Quelques échantillons.

Tous ces individus sont bien conformes au type que j'ai décrit et figuré, mais ils sont de taille très différentes. Voici quelques mesures que je relève sur un certain nombre d'exemplaires :

| $R$ = 50 millim.; | $r$ = 25 millim. | $R$ = 32 millim.; | $r$ = 15 millim. |
|---|---|---|---|
| 47 ,, | 25 ,, | 30 ,, | 14 ,, |
| 42 ,, | 17 ,, | 24 ,, | 10 ,, |
| 35 ,, | 17 ,, | 21 ,, | 10·5 ,, |

*Odontaster Grayi* (Bell).

Voir pour la bibliographie :

LUDWIG, "Asterien und Ophiuren der schwedischen Expedition nach den Magalhaensländern, 1895–1897," *Zeit. für wiss. Zool.*, Bd. lxxxii., p. 44.

1er Décembre 1903, Banc de Burdwood, 54° 25′ lat. S., 57° 32′ long. W.; profondeur 56 brasses. Un échantillon. $R$ = 32 millim.

L'exemplaire est bien conforme au dessin que PERRIER a donné sous le nom d'*Asterodon pedicellaris*, d'après un individu provenant du Cap Horn. Cette espèce est très répandue dans les régions antarctiques et elle a donné lieu à une synonymie assez compliquée qui a été débrouillée par LUDWIG.

*Odontaster pusillus*, nov. sp. (Pl. I. fig. 10 et 11.)

13 Avril 1904, 48° 6′ lat. S., 10° 5′ long. W.; profondeur 1742 brasses. Un seul échantillon. $R$ = 13 millim.; $r$ = 7 millim.

Le disque et les bras sont très aplatis et n'ont que 2 millim. d'épaisseur. Le corps

est polygonal, avec les côtés fortement excavés ; les bras, pointus et triangulaires, sont bien séparés du disque.

La face dorsale offre des plaques bien distinctes, petites, convexes et séparées par des sillons profonds où se montrent les papules. Elles portent sept ou huit piquants disposés en paxilles. Dans la partie centrale, ces plaques sont disposées sans ordre ; mais sur les bras, on reconnait une rangée médiane, et, de chaque côté, une ou deux autres rangées ; elles deviennent plus petites vers les plaques marginales dorsales et forment alors de petites rangées transversales. L'aire paxillaire devient très étroite à mesure qu'on se rapproche de l'extrémité du bras, mais elle se continue jusqu'à cette extrémité. Chaque paxille offre un piquant central entouré d'un cercle périphérique de piquants divergents. Ces piquants sont cylindriques, un peu renflés à l'extrémité qui porte quelques spinules très fines et très courtes.

La plaque madréporique, située à égale distance entre le centre et les plaques marginales, est petite et elle n'offre qu'un petit nombre de sillons.

Les plaques marginales dorsales sont au nombre de dix de chaque côté et il y a en plus une plaque impaire : celle-ci est grande, plus large en dedans qu'en dehors, mais non triangulaire. Les trois ou quatre suivantes sont rectangulaires, plus larges que longues, puis les autres deviennent un peu plus courtes ; la dernière est très petite et triangulaire. La plaque terminale est petite, triangulaire, avec un angle proximal obtus et un bord distal très convexe. Le recouvrement de ces plaques a presque complètement disparu : on reconnait cependant à leur surface des granules allongés, serrés et rugueux, qui, sur le bord externe des plaques, s'allongent en vrais piquants aplatis et un peu élargis à l'extrémité : ils offrent sur leurs bords de fines denticulations. Les plaques marginales dorsales restent séparées les unes des autres jusqu'à l'extrémité des bras.

Le face ventrale du disque offre des plaques à peu près carrées, disposées en rangées régulières longitudinales et obliques. La première rangée, contiguë aux adambulacraires, a les plaques un peu plus grandes que ces dernières, et, en général, deux d'entre elles correspondent à trois adambulacraires. Chaque plaque porte quatre ou cinq piquants allongés, cylindriques et rugueux à l'extrémité, qui est obtuse. Ces piquants diminuent de longueur en s'approchant des plaques marginales ventrales. Tous ces piquants forment un recouvrement assez serré qui empêche de distinguer les contours des plaques sous-jacentes.

Les plaques marginales ventrales correspondent aux dorsales ; comme ces dernières, elles portent des piquants qui, sur leur face inférieure, se présentent sous forme de granules allongés, et qui, vers leur bord externe, se développent beaucoup, s'allongent en même temps qu'ils s'élargissent et s'aplatissent à l'extrémité ; ils constituent ainsi des piquants munis de denticulations très fines comme sur les plaques dorsales.

Les plaques adambulacraires portent, dans le sillon, trois piquants aplatis, obtus et rugueux à l'extrémité et qui sont disposés de manière à former un petit peigne. Sur leur surface ventrale, les plaques adambulacraires sont garnies de quelques piquants qui se disposent généralement en deux rangées.

Les dents offrent sur leur bord libre, une demi-douzaine de piquants identiques aux piquants adambulacraires ; sur leur face ventrale, on trouve deux piquants plus grands, et enfin, couché sur la suture médiane, le gros piquant conique et terminé par une extrémité hyaline qui caractérise le genre *Odontaster*.

Je n'observe de pédicellaires, ni sur la face dorsale, ni sur la face ventrale.

*Rapports et Différences.* — L'exemplaire unique recueilli par la *Scotia* est sans doute un jeune individu, mais il ne peut être rapporté à aucune espèce connue. L'*O. pusillus* est voisin de l'*O. Grayi* (au sens que LUDWIG donne à cette espèce) : il en diffère par ses bras qui sont véritablement distincts, et par le grand développement que prennent les piquants sur le bord libre des plaques marginales dorsales et ventrales. Il se distingue facilement de l'*O. cremeus* Ludwig, qui a les plaques marginales beaucoup plus nombreuses et couvertes de simples granules. On ne peut pas confondre l'*O. pusillus* avec l'*O. penicillatus* : j'ai comparé l'échantillon de la *Scotia* à un exemplaire du Musée de Hambourg, déterminé par MEISSNER et dans lequel $R = 12{\cdot}5$ millim. : les plaques marginales sont au nombre de neuf ; l'animal est infiniment plus robuste ; il est plus épais et sa hauteur atteint 3 millim. environ ; les bras sont plus épais et beaucoup plus larges ; enfin les piquants adambulacraires, beaucoup plus grands et plus forts, ont une disposition différente. L'*O. elongatus* est aussi bien différent. Les autres formes australes voisines appartiennent au genre *Asterodon*.

*Chitonaster Johannæ*, nov. sp. (Pl. IV. fig. 32 à 37.)

18 Mars 1903, 62° 10′ lat. S., 41° 20′ long. W. ; profondeur 1775 brasses. Quatre échantillons.

Les dimensions respectives des exemplaires sont les suivantes :

| | |
|---|---|
| $R = 31$ millim. ; $r = 11$ millim. | $R = 12$ millim. ; $r = 5$ millim. |
| 23 „ 10 „ | 10 „ 4 „ |

Les individus ne sont malheureusement pas intacts, sauf le plus petit ; le suivant n'a que deux bras, l'autre en a trois et le plus grand a conservé quatre bras sur cinq.

Tout l'ensemble de l'animal a une structure très robuste et très solide, et les plaques forment une véritable carapace rigide. Le disque, qui est grand, est très haut et sa hauteur atteint 10 millim. dans le grand échantillon. Les bras sont très larges à la base et leur extrémité est obtuse ; leur face dorsale est aussi très convexe.

La face dorsale est recouverte de plaques irrégulièrement polygonales et inégales, avec les angles arrondis. Ces plaques sont bien séparées et très distinctes dans les deux petits échantillons ; elles sont encore assez distinctes dans le moyen, mais leurs contours sont à peine visibles dans le plus grand, où elles paraissent soudées ensemble. Ces plaques portent de gros granules allongés, robustes et épais, ressemblant plutôt à de petits piquants très courts à extrémité arrondie : ils sont inégaux comme grosseur et comme hauteur. Sur le plus grand individu, ces granules sont au nombre de trois à six

par plaque ; chez les autres ce chiffre varie entre deux et cinq. Les plaques, ainsi que leurs granules, sont disposées sans aucun ordre chez les deux grands exemplaires ; sur les petits, elles forment des cercles concentriques plus ou moins distincts. Sur les bras, les plaques forment des rangées transversales, plus apparentes dans les grands exemplaires que dans les petits. Dans ces deux derniers, les granules sont moins nombreux que dans les grands.

On est absolument surpris de rencontrer, sur certaines de ces plaques, de gros pédicellaires valvulaires dont la longueur peut atteindre 2 millim. dans le grand individu, et qui occupent une région assez importante de la plaque tout en laissant place à deux ou trois petits granules sur les côtés. Sur le grand échantillon, je compte sept pédicellaires, occupant tous une position interradiale, mais disposés d'une manière tout à fait irrégulière ; la plupart se trouvent au voisinage du bord du disque, un seul est situé près du centre. L'exemplaire moyen offre cinq pédicellaires, un peu plus petits et toujours disposés sans ordre. Les deux petits individus n'ont pas de pédicellaires sur la face dorsale : cependant je remarque, sur une plaque de l'échantillon chez lequel $R = 12$ millim., deux épaississements allongés et contigus qui paraissent bien correspondre à un pédicellaire en voie de développement (ainsi que je le dirai plus loin, ce même exemplaire possède sur la face ventrale des pédicellaires parfaitement développés).

La plaque madréporique est plutôt petite, arrondie, avec des sillons qui partent du centre en rayonnant irrégulièrement ; elle est placée un peu plus près du bord que du centre du disque.

Les plaques marginales dorsales sont au nombre de dix-huit à dix-neuf dans le grand exemplaire. Ces plaques se font remarquer par la disposition très régulière de leurs granules formant une rangée transversale de quatre, qui est perpendiculaire à l'axe du bras ; de plus, on trouve en général un petit granule accessoire.

La plaque apicale est très apparente : elle est arrondie et un peu plus large que longue ; elle n'occupe pas toute la largeur du bras dans les deux grands exemplaires et elle est comparativement plus grande dans les deux petits où elle occupe toute l'extrémité du bras ; elle offre à sa surface quelques petits granules.

Les plaques latéro-ventrales sont peu nombreuses et leurs contours sont cachés par les téguments. Dans le grand exemplaire, la rangée parallèle aux adambulacraires comprend cinq ou six plaques ; en dehors, deux ou trois plaques complètent la face ventrale. En principe, chaque plaque parait porter un petit piquant cylindrique et obtus avec deux ou trois granules, mais le piquant peut manquer et les granules se montrent seuls ; d'ailleurs l'ordre est parfois modifié par la transformation de piquants en pédicellaires. Dans le grand exemplaire, on peut voir un pédicellaire dans chaque interradius : quatre de ces pédicellaires se trouvent placés immédiatement en dehors des dents, le cinquième en est un peu éloigné. Je remarque en outre que dans trois interradius, le pédicellaire est placé longitudinalement et dans les deux autres transversalement par rapport à l'axe interradial. Ces cinq pédicellaires sont les seuls qu'offre

cet échantillon et l'on voit que leur disposition est assez régulière. Sur l'exemplaire moyen, les pédicellaires sont beaucoup plus irrégulièrement placés et se montrent en n'importe quel point de la face ventrale ; deux ou trois d'entre eux seulement sont définitivement formés, les autres consistent en un granule allongé et qui n'est pas encore fendu ; enfin quelques plaques adambulacraires portent aussi un pédicellaire. Dans l'exemplaire chez lequel $R = 12$ millim., je note un pédicellaire sur une des plaques latéro-ventrales, un autre sur une plaque marginale ventrale et trois sur les adambulacraires. Le plus petit individu est totalement dépourvu de pédicellaires.

Les plaques marginales ventrales correspondent aux dorsales. Sur le grand exemplaire leur armature est généralement disposée de la manière suivante : en bas, un granule allongé ; au milieu, un granule plus gros et plus long formant un vrai piquant ; en haut, deux granules plus petits. Sur certaines plaques cependant, je n'observe que trois granules dont le médian est plus grand. Cette disposition est la règle sur le moyen exemplaire. Dans les deux petits, il y en a généralement quatre par plaque : un inférieur, un moyen et deux supérieurs.

Les sillons ambulacraires sont plutôt étroits ; les tubes ambulacraires sont très régulièrement bisériés et sont terminés par une large ventouse.

Chaque plaque adambulacraire porte, dans le sillon, deux piquants inégaux : le piquant proximal est allongé, cylindrique et obtus à l'extrémité, l'autre est plus court et ressemble plutôt à un granule allongé ; parfois, on observe un granule supplémentaire en avant du piquant. Sur la face ventrale de la plaque, se dresse un piquant cylindrique et obtus. Dans les petits exemplaires, les deux piquants du sillon sont subégaux et plus petits que le piquant ventral. On a déjà vu plus haut que les plaques adambulacraires elles-mêmes peuvent présenter des pédicellaires : ceux-ci sont d'ailleurs peu nombreux.

La couleur des échantillons est gris-jaunâtre.

*Rapports et Différences.*—La découverte d'une nouvelle espèce du genre *Chitonaster* est très intéressante, car ce genre n'était jusqu'à maintenant représenté que par une seule espèce, elle-même créée d'après un exemplaire unique. La présence de pédicellaires valvulaires dans l'espèce recueillie par la *Scotia*, pédicellaires qui n'existaient pas chez le *Ch. cataphractus*, permet de fixer d'une manière définitive la position de ce genre dans la famille des Pentagonastéridées, où SLADEN l'avait placé avec quelque doute.

Le type du *Challenger* provient des mers australes ; comme il a été recueilli par 62° 26′ lat. S. et 95° 44′ long. E., on voit que les deux espèces se sont rencontrées sur la même latitude, mais, en revanche, se trouvent dans des localités très éloignées en longitude.

Le *Ch. cataphractus* a été décrit par SLADEN d'après un individu dont les dimensions étaient : $R = 16{\cdot}5$ millim. et $r = 5$ millim. ; celui-ci était donc intermédiaire, comme taille, entre le deuxième et le troisième des exemplaires de la *Scotia*. La différence la plus importante entre les deux espèces consiste en la présence de pédicellaires valvulaires qui font complètement défaut chez le *Ch. cataphractus* ; cette différence ne peut pas

être attribuée à une différence d'âge puisque ces pédicellaires existent chez un exemplaire de *Ch. Johannæ* dans lequel $R$ n'a que 12 millim. D'ailleurs, la disposition de piquants adambulacraires et l'armature des plaques marginales dorsales et ventrales, diffèrent chez les deux espèces : enfin la face dorsale du disque et des bras chez le *Ch. Johannæ* est garnie de granules et non pas de vrais piquants.

### *Marcelaster*, nov. gen.

Le genre *Marcelaster* est voisin du genre *Pararchaster*, dont il offre le facies général et les plaques marginales dorsales étroites, mais il n'existe pas de plaque marginale impaire : aux lieu et place de celle-ci, on voit dans l'arc interbrachial un groupe de plaques latéro-dorsales portant une touffe de grands piquants qui recouvrent la première plaque marginale dorsale de chaque côté : cette plaque est un peu plus petite que les suivantes. Les plaques dorsales du disque et des bras sont couvertes de piquants disposés en paxilles. On distingue, sur la face dorsale du disque, un certain nombre de plaques plus grandes que les autres et munies chacune d'un gros piquant central : ces plaques paraissent disposées suivant un certain ordre : il y a une plaque centrale et des plaques radiales et interradiales. Il n'y a pas de plaques latéro-ventrales (du moins sur les individus que j'ai étudiés). Les plaques marginales dorsales et ventrales offrent chacune un piquant grand et fort, entouré de quelques autres plus petits. Les plaques adambulacraires portent, sur leur face ventrale, un ou deux grands piquants.

### *Marcelaster antarcticus*, nov. sp. (Pl. III. fig. 22 à 25.)

18 Mars 1903, 62° 10′ lat. S., 41° 20′ long. W. ; profondeur 1775 brasses. Trois échantillons dont un entier et en excellent état, un autre un peu plus petit et incomplet ; le dernier est très petit.

Dans le plus grand individu, $R = 33$ millim. et $r = 8{\cdot}5$ millim. ; dans le plus petit, $R = 10$ millim.

Le disque est de dimensions moyennes et peu élevé. Les bras sont aplatis et minces : ils mesurent environ 7 millim. de largeur à leur origine, puis ils vont en s'amincissant graduellement jusqu'à l'extrémité qui est émoussée.

La face dorsale du disque et des bras est couverte de plaques arrondies, un peu inégales, munies de piquants dressés obliquement et divergents qui figurent des paxilles : les plus grandes de ces paxilles sont formées de sept ou huit piquants, disposés ou non autour d'un piquant central. Les paxilles plus petites, qui se montrent sur le bord du disque ou sur les bras, n'ont que quatre, trois ou même deux piquants : ceux-ci sont allongés, cylindriques, obtus à l'extrémité et légèrement rugueux. Les plaques sont complètement cachées par ces piquants qui s'entrecroisent et s'enchevêtrent même d'une paxille à l'autre, et leurs limites n'apparaissent que lorsqu'on a fait tomber les piquants :

même ces limites ne sont pas toujours très précises, car les plaques sont réunies à leur base par une tissu calcifié commun. Dans la région centrale du disque, un certain nombre de plaques plus grandes que les autres portent, au centre des piquants qui forment la paxille, un grand piquant fort, cylindrique, trapu, obtus à l'extrémité et ayant au moins 2 millim. de longueur. Le grand exemplaire offre une douzaine de ces piquants, parmi lesquels on peut distinguer un piquant central et au moins deux piquants par radius et par interradius. La disposition régulière de ces piquants est mieux marquée sur l'individu en mauvais état. Sur le petit exemplaire que je décrirai plus bas, on reconnait nettement une plaque centro-dorsale, et, séparées d'elle par deux ou trois rangs de petites plaques, cinq plaques interradiales presque aussi grandes qu'elle et cinq plaques radiales plus petites (Pl. III. fig. 25).

La plaque madréporique, rapprochée d'un arc interbrachial, est petite et offre quelques sillons. L'anus se présente sous forme d'une ouverture très petite, placée à côté de la paxille centrale.

Vers chaque arc interbrachial, un certain nombre de plaques dorsales portent chacune un ensemble de piquants allongés, généralement disposés en trois rangées sur chaque plaque : quatre dorsaux assez courts et à peine plus longs que ceux qui forment les paxilles voisines, quatre moyens plus longs et enfin trois ou quatre externes beaucoup plus longs. Tous ces piquants s'entrecroisent et constituent, par leur ensemble, une touffe serrée qui recouvre le fond de l'arc interbrachial. Lorsque l'on enlève ces piquants, on constate que les plaques qui les portent sont au nombre de sept : trois de chaque côté de l'angle interradial et une impaire située exactement au dessus de la suture qui sépare la première plaque marginale dorsale de sa congénère (fig. 24).

Les plaques marginales dorsales sont au nombre de dix-huit ; il n'y a pas de plaque impaire comme chez les *Pararchaster*, mais la première plaque de chaque série est plus petite que les suivantes. Ces plaques sont longues mais très minces et elles ne sont pas bien séparées les unes des autres, car leurs faces latérales, d'ailleurs très étroites, sont plus ou moins confluentes : elles forment plutôt, par leur ensemble, une sorte de bordure offrant des épaississements de distance en distance. Chaque plaque marginale porte un gros piquant principal, dressé obliquement, cylindrique et obtus, à surface rugueuse, entouré à la base d'un cercle de sept ou huit piquants beaucoup plus petits. La première plaque marginale, qui est plus petite, ne possède en général pas de piquant principal, mais seulement un groupe de cinq ou six piquants allongés.

Il n'y a pas de plaques latéro-ventrales et les plaques marginales ventrales succèdent immédiatement aux adambulacraires. Ces plaques correspondent aux dorsales ; chacune d'elles est munie, en son milieu, d'un grand piquant plus développé que le piquant correspondant des plaques dorsales et entouré d'un cercle de piquants beaucoup plus petits. Sur les premières plaques de chaque série, on remarque qu'un ou deux de ces petits piquants s'allongent, surtout le piquant qui est placé immédiatement en dedans du piquant principal.

Les plaques adambulacraires portent, dans le sillon, trois piquants allongés, cylin-

driques, le médian plus long que les deux autres. Sur leur face ventrale, on remarque un, et parfois deux gros piquants allongés et très forts, plus gros que les piquants du sillon, et en outre quelques piquants plus petits, dont l'un est souvent dirigé en dedans, ce qui porte à quatre le nombre des piquants du sillon. Les sillons ambulacraires sont de moyenne largeur. Les tubes ambulacraires sont disposés en deux séries très régulières et terminés par une ventouse convexe aussi large que le diamètre du tube.

Les dents portent sur leur bord libre une rangée de huit à dix piquants plus petits que les piquants ambulacraires, et, sur leur face ventrale, une rangée de trois ou quatre grands piquants.

Le petit échantillon, qui n'a pas encore acquis les caractères de l'adulte, présente certaines particularités qu'il est intéressant de noter (Pl. III. fig. 25). La face dorsale du disque et des bras est couverte de petites plaques arrondies ou irrégulièrement polygonales. On ne distingue pas de rangée carinale, mais seulement onze plaques primaires très apparentes : une grande plaque centro-dorsale, cinq radiales plus petites qu'elle, situées au milieu de la base du bras, et cinq interradiales plus grandes. Chacune de ces onze plaques est munie d'un grand piquant entouré de quelques autres plus petits. Les autres plaques portent des groupes de trois à cinq petits piquants. Les plaques marginales dorsales sont au nombre de huit et chacune d'elles porte un gros piquant et quelques autres plus petits ; la première plaque est un peu plus petite que les suivantes. Ces plaques sont étroites et se touchent par leurs bords amincis ; il n'y a pas la moindre indication de plaque impaire. Les plaques dorsales qui avoisinent l'angle interradial ne diffèrent pas des voisines. La plaque terminale est grande et bombée, et elle est échancrée sur son bord proximal de manière à recevoir la dernière plaque dorsale du bras. Vers son bord libre, elle offre deux gros piquants latéraux divergents et quelques autres piquants plus petits. Les plaques marginales ventrales portent chacune un gros piquant et d'autres plus petits. Les plaques adambulacraires présentent trois piquants dans le sillon, et, sur leur face ventrale, deux gros piquants accompagnés de quelques autres plus petits ; à une certaine distance de la base du bras, on ne distingue plus qu'un seul piquant principal.

*Ganeria attenuata*, nov. sp. (Pl. III. fig. 26 et 27.)

18 Mars 1903, 62° 10′ lat. S., 41° 20′ long. W. ; profondeur 1775 brasses. Un seul échantillon.

$R = 35$ à 38 millim. ; $r = 11$ à 12 millim.

L'échantillon était assez fortement contourné et replié sur lui-même : j'ai pu arriver, en le desséchant, à le redresser et à lui donner la forme sous laquelle je l'ai photographié.

La face dorsale est convexe et la face ventrale concave, mais il est certain que cette forme est due à l'attitude défectueuse prise par l'exemplaire conservé, qui, à l'état vivant,

devait être aplati et mince. Les bras sont étroits à la base et ils s'amincissent graduellement jusqu'au sommet qui est pointu. Le bord du disque et des bras est très mince.

La face dorsale du disque et des bras est couverte de petites plaques à contours irréguliers, dont chacune porte un piquant court, obtus à l'extrémité qui est rugueuse, et parfois même terminée par deux ou trois spinules très courtes; la base du piquant est élargie, mais le reste est cylindrique. Il y a parfois deux piquants par plaque. Les plaques, ainsi que les piquants, sont disposées sans aucun ordre et elles ne forment pas de séries. Il existe un anus central, petit, sur lequel sont rabattus quelques piquants. La plaque madréporique est petite, située près du centre: elle est un peu saillante et elle offre à sa surface quelques granules rugueux très aplatis. Sur les bords du bras, les plaques s'allongent en une rangée marginale assez régulière et elles portent généralement chacune un petit peigne de trois piquants, mais ceux-ci sont ordinairement cassés, et, en tous cas, couchés et enchevêtrés les uns dans les autres: aussi est-il bien difficile de les distinguer.

Les plaques de la face ventrale n'ont pas de contours distincts; elles portent des piquants assez forts, allongés, cylindriques, à extrémité obtuse et disposés sans ordre. Les plaques marginales ventrales sont très minces et portent chacune deux piquants identiques aux autres piquants ventraux et qui sont plus ou moins confondus avec ces derniers ainsi qu'avec les piquants des plaques marginales dorsales.

Le sillon ambulacraire est de largeur moyenne; les tubes ambulacraires sont bisériés. Les plaques adambulacraires portent dans le sillon un piquant oblique, et, sur leur face ventrale, deux piquants forts et cylindriques, l'interne un peu plus grand que l'autre.

Les dents sont munies sur leur bord libre de quatre ou cinq piquants identiques aux piquants adambulacraires qu'ils continuent. Sur leur face ventrale, on trouve quelques piquants formant une rangée irrégulière et qui se continuent avec les autres piquants de la face ventrale du corps.

*Rapports et Différences.*—La *G. attenuata* se distingue des autres espèces du genre par ses plaques dorsales qui ne portent qu'un seul piquant.

### *Scotiaster*, nov. gen.

Le genre *Scotiaster* est voisin du genre *Ganeria*, dont il diffère par le peu de développement du squelette dorsal. La face dorsale reste assez molle, et les plaques calcaires, cachées sous les téguments, ne sont pas apparentes: elles sont sans doute rudimentaires. On n'observe, sur cette face, que de petits tubercules ou granules espacés qui, sur les côtés des bras, se disposent en petites rangées transversales. Ces granules, peu développés, n'apparaissent qu'à travers un mince tégument. Les plaques marginales dorsales et ventrales sont peu apparentes et les dorsales ne sont même visibles qu'à l'extrémité des bras. Les plaques ventrales ont des contours indistincts et portent des piquants allongés.

Bien que le genre *Scotiaster* soit très voisin du genre *Ganeria*, il m'a paru nécessaire

de l'en séparer en raison du caractère de la face dorsale, qui est à peu près dépourvue de tout recouvrement et n'offre que quelques granules. On ne peut supposer que cette face ait porté chez l'animal vivant quelques formations telles que piquants ou autres, qui seraient tombés accidentellement : en effet, l'exemplaire unique qui m'a été remis parait en excellent état et la face dorsale offre un tégument mince qui passe par dessus les granules ; les papules sont bien conservées et bien apparentes.

Le genre *Scotiaster* est donc caractérisé par une réduction évidente du squelette et des piquants de la face dorsale ; les piquants de la face ventrale eux-mêmes sont mous.

*Scotiaster inornatus*, nov. sp. (Pl. IV. fig. 38 et 39.)

9 Avril 1904, 51° 7′ lat. S., 9° 31′ long. W. ; profondeur 2103 brasses. Un seul échantillon.

$R = 38$ à 40 millim. ; $r = 15$ millim.

Le disque est grand ; les bras, triangulaires, s'insèrent sur le disque par une large base et vont en se rétrécissant rapidement jusqu'à l'extrémité qui est obtuse. L'animal est sans rigidité et les bras peuvent être reployés sur eux-mêmes.

La face dorsale du disque est molle et se laisse déprimer facilement. Elle présente un tégument mince, sous lequel apparaissent de petits tubercules très peu proéminents, épars, disposés sans ordre, largement séparés les uns des autres. Sur les bras cependant ces tubercules deviennent plus serrés et ils se disposent en petites files transversales, assez rapprochées les unes des autres et s'étendant d'une bande médiane irrégulière jusqu'aux plaques marginales dorsales. Ces dernières ne sont apparentes, ni dans l'arc interbrachial, ni au commencement du bras, et elles ne sont guère visibles qu'à partir de la deuxième moitié : elles se montrent sous forme de légers soulèvements qui deviennent plus marqués vers l'extrémité du bras et qui correspondent aux marginales ventrales, lesquelles sont mieux marquées. Chaque plaque porte un ou deux granules identiques à ceux qu'on voit sur la face dorsale. Entre les granules, se montrent des papules allongées qui sont nombreuses mais isolées. La plaque madréporique, située à peu près à égale distance entre le centre et le bord, est petite et arrondie ; elle offre des sillons qui partent en rayonnant du centre.

Les contours des plaques latéro-ventrales sont absolument indistincts. Ces plaques sont recouvertes d'un mince tégument et elles portent des piquants allongés, très larges à la base, coniques, pointus et très rapprochés les uns des autres ; ces piquants ne sont pas rigides, ils sont souvent un peu incurvés et leur extrémité est molle : au microscope, ils se montrent constitués par une tige calcaire enveloppée d'une gaine tégumentaire assez épaisse. Ils forment des séries parallèles aux adambulacraires et d'autres séries plus apparentes rejoignant, en direction radiaire, les marginales ventrales. Ces piquants deviennent plus petits à mesure qu'on s'approche de ces dernières, et il est possible que chacun d'eux corresponde à une plaque. Pour s'en assurer, il aurait fallu traiter à la

potasse une partie de la face ventrale, mais je n'ai pas osé le faire, l'exemplaire étant très mou et pouvant être fortement endommagé par ce traitement.

Les contours des plaques marginales ventrales ne sont pas bien distincts : chacune d'elles porte une petite rangée transversale de deux ou trois piquants très courts, et ce sont ces derniers qui rendent apparentes les plaques marginales.

Le sillon ambulacraire est large. Les tubes ambulacraires sont irrégulièrement bisériés, parfois trisériés : ils tranchent nettement par leur coloration brun-foncé sur la face ventrale, qui est très claire et d'un blanc-jaunâtre. Les plaques adambulacraires portent, dans le sillon, deux piquants, et l'on en retrouve deux autres sur leur face ventrale : ces piquants sont grands, coniques et ils ressemblent aux piquants du reste de la face ventrale.

Les dents présentent sur leur bord libre trois piquants, dont le proximal est plus allongé et plus gros ; sur leur face ventrale, se montre un grand piquant dirigé obliquement en avant, au dessous du piquant terminal.

La couleur générale est blanc-jaunâtre, avec les tubes ambulacraires très foncés, ainsi que je l'ai dit plus haut.

*Retaster verrucosus*, Sladen.

SLADEN, *Reports of the "Challenger" : Asteroidea*, p. 478, pl. lxxvi., fig. 1–2, et lxxvii., fig. 9–10.

1er Decembre 1903, Banc de Burdwood, 54° 25′ lat. S., 57° 32′ long. W. ; profondeur 56 brasses. Un échantillon.

$R = 38$ à 40 millim. ; $r = 25$ à 28 millim.

Les bras sont plus courts et les espaces interbrachiaux moins excavés que dans le type décrit par SLADEN, mais je ne crois pas devoir l'en séparer sur ce seul caractère qui peut varier. La tente dorsale est très épaisse et plissée, et on ne peut pas y distinguer de faisceaux de fibres : SLADEN dit que cela arrive chez les individus adultes.

Le type de l'espèce provient de l'entrée du détroit de Magellan, côté de l'Atlantique, par 55 brasses de profondeur.

*Hymenaster campanulatus*, nov. sp. (Pl. I. fig. 8 et 9 ; Pl. II. fig. 19 à 21.)

18 Mars 1904, 71° 22′ lat. S., 16° 34′ long. W. ; profondeur 1410 brasses. Un seul échantillon.

$R = 11$ à 12 millim. ; $r = 7$ millim.

Le corps est remarquablement haut et sa forme peut être très exactement comparée à celle d'une cloche dont la base se prolongerait en cinq lobes triangulaires, terminés en pointes obtuses correspondant aux bras ; la hauteur totale, comptée depuis l'extrémité des bras, est de 12 millim. La face ventrale est très profondément excavée. Le bord du corps n'est pas frangé.

La tente dorsale est fine et transparente et les fibres y paraissent très faiblement développées. Les piquants des paxilles la soulèvent en proéminences fortes, coniques, rugueuses et disposées assez régulièrement : on en compte de cinq à huit par paxille. Les spiracules, arrondis ou ovalaires, et limités par un cercle très légèrement saillant, sont disposés assez régulièrement entre les proéminences de la face dorsale, tantôt sur un seul rang, tantôt sur deux, suivant leur grosseur. L'orifice osculaire est petit ; les valves sont formées par cinq ou six piquants gros et forts, libres dans leur partie terminale : les deux piquants externes sont très petits, les médians, plus longs, sont à peu près égaux.

Les sillons ambulacraires vont en s'élargissant jusque près de l'extrémité du bras, sans atteindre d'ailleurs une grande largeur, puis ils se rétrécissent rapidement. Les piquants adambulacraires, au nombre de trois, forment un peigne un peu oblique : ils sont minces et pointus ; l'interne est dirigé vers le sillon, l'externe, un peu plus long, est dirigé obliquement vers le bas, enfin le médian, qui est le plus long, se dirige obliquement en dedans. En certains points, ces piquants se montrent réunis par une membrane très nette. Les papilles des orifices segmentaires ont une forme que l'on observe rarement dans le genre *Hymenaster* et qui rappelle celle de l'*H. præcoquis* Sladen : c'est une petite plaque ovalaire, qui n'est libre que sur son bord distal et qui est adhérente par l'autre côté en ne laissant libre qu'un orifice étroit et arqué.

Les dents sont petites et se réunissent en une plaque à peu près aussi longue que large ou un peu plus large que longue, dont le milieu porte une saillie ovoïde (Pl. II. fig. 21). Chacune d'elles se termine par un gros piquant très fort et épais, cylindrique, à extrémité obtuse, dont la longueur égale au moins le double de la longueur de la dent ; ce piquant est dirigé obliquement et il forme avec son congénère une fourche très apparente, dont les branches s'enchevêtrent avec les autres piquants. Au dessus et un peu en dedans de ce piquant, on observe un piquant dorsal plus petit que le précédent et formant également avec son congénère une fourche, mais dont les deux branches sont moins divergentes. Ces deux piquants paraissent être les seuls que portent les dents, et je ne puis découvrir de piquants dentaires latéraux, mais, pour être sûr de leur absence, il faudrait disséquer l'exemplaire. Ainsi constituées, les dents offrent une physionomie très particulière.

Les piquants de la face ventrale sont assez forts ; les sept ou huit premiers piquants de chaque série convergent ou se touchent vers la ligne interradiale médiane et leur longueur augmente progressivement. A leur suite, viennent une quinzaine de piquants dont la longueur diminue peu à peu et qui deviennent très courts ; ils dépassent légèrement de leur extrémité obtuse le bord du corps.

La couleur générale est blanc-jaunâtre.

*Rapports et Différences.*—L'*H. campanulatus* est évidemment voisin de l'*H. præcoquis* Sladen, avec lequel il partage la forme particulière de la papille segmentaire, et il offre, comme lui, trois piquants adambulacraires, mais il s'en distingue par la forme générale, qui est complètement différente, et par la structure de l'appareil dentaire.

Sladen s'était demandé s'il n'y aurait pas lieu de placer l'*H. præcoquis* dans un genre à part, en raison de la forme spéciale de la papille segmentaire, et, finalement, il s'est décidé à le laisser dans le genre *Hymenaster*. Je ne crois pas qu'il y ait inconvénient à faire rentrer dans ce genre l'*H. campanulatus*, mais il est certain que les deux espèces forment une section à part dans les *Hymenaster*.

*Hymenaster edax*, nov. sp. (Pl. II. fig. 12 à 15.)

18 Mars 1903, 62° 10′ lat. S., 41° 20′ long. W. ; profondeur 1775 brasses. Trois échantillons.

$R = 10$ à 11 millim. ; $r = 6$ millim.

La forme du corps est pentagonale, avec les côtés excavés de manière à former des bras courts, triangulaires, dont la base dépasse la longueur, à extrémité très obtuse. Les faces dorsale et ventrale sont toutes deux convexes, avec les bords minces et tranchants : ils offrent une frange très étroite, traversée par les extrémités des piquants.

La tente dorsale, mince, est soulevée par les piquants des paxilles en éminences coniques qui sont à peu près toutes de mêmes dimensions sur le disque, où elles sont disposées irrégulièrement : elles ont cependant une tendance à se réunir en groupes de quatre à six ; elles deviennent plus nombreuses, plus serrées et plus petites sur les bras, où elles forment parfois des rangées obliques plus ou moins apparentes. Les fibres sont assez distinctes et elles se divisent un peu comme chez l'*H. coccinatus* Sladen, mais les spiracules sont beaucoup plus nombreux que dans cette dernière espèce ; ces spiracules sont plutôt grands, inégaux, circulaires ou ovalaires, avec un contour légèrement proéminent. Ils forment généralement un cercle plus ou moins régulier à la base de chaque éminence, et l'on en trouve d'autres dans les intervalles. L'oscule est petit ; les cinq valves qui le limitent sont formées chacune par cinq ou six gros piquants striés, qui deviennent libres dans leur moitié externe.

Les quatre ou cinq premiers piquants de la face ventrale se touchent, ou tout au moins sont très rapprochés sur la ligne interradiale médiane, et ils s'allongent rapidement du premier au sixième, puis la longueur diminue progressivement : il y en a dix-huit en tout environ. Les extrémités des piquants au delà du cinquième sont libres et forment une très légère saillie au dehors.

Le sillon ambulacraire est large et un peu pétaloïde.

La première plaque adambulacraire porte trois piquants ; les trois ou quatre suivantes en ont quatre, et ce chiffre retombe à trois sur les autres ; ces piquants sont allongés, forts, pointus, divergents, et ils forment un peigne oblique dans lequel le piquant externe est le plus long.

Les papilles qui recouvrent les orifices segmentaires sont allongées, lancéolées, et leur forme rappelle celle que Sladen a indiquée chez l'*H. coccinatus*, mais elles n'offrent qu'une côte médiane et deux latérales.

Les dents sont peu développées et elles se réunissent en une petite proéminence qui ne sert, en somme, que de support à trois piquants très forts et très gros, allongés, cylindriques, obtus à l'extrémité qui offre quelques rugosités. Il y a, sur le côté de la dent, un piquant dirigé en arrière, et, à l'extrémité, deux piquants superposés dirigés en avant.

La coloration générale est grise.

*Rapports et Différences.*—L'*H. edax* est surtout voisin de l'*H. coccinatus* Sladen, mais il en diffère par la disposition des piquants adambulacraires et par les dents très petites et munies de trois piquants considérablement développés. Il rappelle aussi l'*H. campanulatus* que j'ai décrit ci-dessus, mais il s'en écarte immédiatement par sa forme aplatie et par le nombre des piquants adambulacraires.

*Hymenaster fucatus*, nov. sp. (Pl. III. fig. 28 à 31.)

18 Mars 1904, 71° 22′ lat. S., 16° 34′ long. W.; profondeur 1410 brasses. Deux échantillons.

Les deux individus ont à peu près les mêmes dimensions : $R = 24$ millim. ; $r = 15$ millim.

L'un des deux exemplaires est en bon état : il est d'une couleur uniformément grise. L'autre était recouvert de vase dont il a été impossible de le débarrasser complètement sur la face dorsale et dans les sillons ambulacraires : sa face dorsale offre la couleur gris-foncée de la vase, tandis que la face ventrale est rougeâtre.

Le corps est pentagonal avec les côtés plus ou moins excavés. Dans l'exemplaire en bon état, les bras ne sont pas en général bien distincts, tandis qu'ils sont beaucoup mieux marqués sur l'autre individu. La face dorsale est à peu près plane et la face ventrale un peu convexe. Le corps est limité par une frange mince que les piquants dépassent légèrement.

La tente dorsale s'étend uniformément sur les spinules des paxilles qui la soulèvent de distance en distance en petites éminences coniques irrégulièrement distribuées et traversées par l'extrémité des spinules : on voit partir de ces proéminences de petites fibres se perdant bientôt dans les intervalles qui restent plans. En certains points, surtout sur la face dorsale des bras, ces spinules forment des groupes de trois à cinq. Les spiracules sont petits, irrégulièrement disposés entre les proéminences de la tente : ils sont peu nombreux et peu serrés et limités par un rebord peu épaissi. L'oscule est large ; les valves sont formées chacune par sept ou huit longs piquants parallèles, les deux externes un peu plus courts que les autres.

Les sept ou huit premiers piquants de la face ventrale convergent vers le milieu de la ligne médiane interradiale sans se toucher généralement, et leur longueur augmente régulièrement du premier au sixième ; les autres piquants, qui vont en diminuant progressivement, sont au nombre d'une quinzaine. Tous ces piquants sont épais et forts, cylindriques et assez espacés.

Les plaques adambulacraires portent généralement trois piquants assez gros et allongés, obtus à l'extrémité : ils sont réunis par une membrane et disposés en un peigne oblique ; l'interne est un peu plus petit. La première plaque adambulacraire ne porte que deux piquants et c'est ce chiffre que l'on observe souvent au delà de la deuxième moitié du bras.

Les orifices segmentaires sont recouverts d'une papille bien développée, plutôt simplement ovalaire dans l'exemplaire le mieux conservé, tandis que dans l'autre elle est nettement fusiforme et se prolonge en une pointe mousse comme chez l'*H. coccinatus* Sladen ; on rencontre d'ailleurs dans le premier échantillon des papilles offrant cette forme. Ces papilles offrent, à leur surface, des côtes plus ou moins accusées, et l'on peut distinguer une côte médiane plus forte et deux côtes latérales, comme SLADEN l'a décrit et figuré chez l'*H. coccinatus* ; c'est la côte médiane qui se prolonge en une pointe plus ou moins marquée. La première papille est beaucoup plus grande que les suivantes.

Les dents ne sont pas très développées. Elles forment, en s'affrontant sur la ligne médiane, une carène saillante et arrondie, terminée en pointe libre aux deux extrémités et dirigée obliquement. De chaque côté de la carène, on trouve deux gros piquants placés l'un derrière l'autre, et, sur le bord des expansions latérales, une rangée de cinq petits piquants subégaux ou diminuant légèrement de longueur et de taille depuis le piquant proximal jusqu'au dernier.

*Rapports et Différences.*—L'*H. fucatus* se rapproche de l'*H. latebrosus* Sladen, dont il diffère par les éminences de la tente dorsale, moins fortes, plus écartées et séparées par de grands intervalles où se trouvent les spiracules, qui sont peu nombreux ; par les dents plus saillantes avec une rangée marginale de cinq petits piquants, par les piquants adambulacraires inégaux et par la première paire de papilles segmentaires plus développée.

*Hymenaster densus*, nov. sp. (Pl. I. fig. 4 à 7.)

21 Mars 1904, 69° 33′ lat. S., 15° 19′ long. W. ; profondeur 2620 brasses. Deux échantillons, qui, malgré leur apparence extérieure, ne sont pas en très bon état ; les piquants adambulacraires et dentaires notamment, sont presque tous brisés.

Dans le plus grand exemplaire, la forme générale est ovoïde et le corps est allongé dans un sens, de telle sorte que les rayons sont très inégaux : en mesurant les plus grandes dimensions, je trouve $R = 25$ à 26 millim. et $r = 12$ à 14 millim. Dans le plus petit, dont le corps est régulièrement pentagonal, $R = 12$ millim. et $r = 8$ millim.

Je décrirai d'abord le grand individu.

La face dorsale est peu bombée ; la face ventrale est, au contraire, convexe et fortement bombée ; les bras sont fortement recourbés et rabattus sur la face dorsale du disque ; ils sont allongés et terminés en pointe obtuse.

La tente dorsale est assez épaisse et opaque. Les paxilles, serrées et rapprochées, se terminent par cinq ou six piquants lisses, allongés, assez robustes, à extrémité obtuse et presque horizontaux. Au centre de chaque groupe, se montre un piquant central plus court. En certains points, ces groupes sont bien distincts et il en est sans doute ainsi chez l'animal vivant, mais, en général, ils sont plus ou moins enchevêtrés. Les fibres sont indistinctes. Les spiracules sont peu nombreux, petits et épars. L'oscule est petit ; les valves, très réduites, sont couchées les unes sur les autres, et je ne puis distinguer les piquants qui les forment.

Les sillons ambulacraires sont larges et ils s'élargissent jusqu'aux points où les bras se retroussent pour se rabattre sur la face dorsale. Les piquants adambulacraires sont fort endommagés et il est très difficile de les compter. J'en reconnais en général quatre : l'interne petit et conique, les autres sont allongés, grêles et pointus ; presque tous sont brisés.

Les dents sont allongées, minces, saillantes et elles se réunissent pour former une proéminence en forme de crête très développée qui ne porte aucun piquant. Sur le prolongement latéral, et contre la crête, s'insèrent deux piquants allongés : l'interne est le plus long et sa longueur est presque égale à celle de la dent. Trois autres piquants, plus fins et plus courts, se montrent sur le bord libre.

Les papilles segmentaires sont petites et ovalaires et terminées à leur extrémité libre par deux ou trois petits prolongements.

Les cinq ou six premiers piquants ventraux convergent, à l'exception de ceux de la première paire, vers le milieu de l'arc interbrachial. A la suite, viennent cinq ou six piquants dont la longueur diminue rapidement ; puis les bras se relèvent sur la face dorsale et les piquants, d'ailleurs très petits, deviennent très difficiles à compter. Sur la face ventrale, chaque piquant se trouve assez souvent accompagné d'un petit piquant accessoire beaucoup plus grêle.

Le petit exemplaire a les bras beaucoup moins relevés que le grand. Les paxilles sont très serrées et les piquants qui les forment sont rugueux. Je distingue, dans les valves de l'oscule, des piquants distincts, mais ces valves sont si fortement rabattues les unes sur les autres qu'il est impossible de compter les piquants de chacune d'elles. Les piquants adambulacraires paraissent réunis par une membrane, mais ils ne sont pas mieux conservés que sur le grand exemplaire ; il en est de même des dents.

*Rapports et Différences.*—Bien que je n'aie pas pu étudier d'une manière complète les caractères des piquants adambulacraires et des dents, il est évident que l'*H. densus* ne peut être rapporté à aucune espèce déjà connue possédant plus de trois piquants adambulacraires.

*Cribrella Pagenstecheri*, Studer.

Voir pour la bibliographie :

LEITPOLDT, " Asteroidea der Vettor Pisani Expedition," *Zeit. f. wiss. Zool.*, Bd. lix., pp. 578–584 (*C. Pagenstecheri*).
MEISSNER, *Hamburger Magalhaensische Sammelreise : Asteroideen*, p. 13.
LUDWIG, " Asterien und Ophiuren der schwedischen Expedition," *Zeit. f. wiss. Zool.*, Bd. lxxxii., p. 68.

1er Décembre 1903, banc de Burdwood, 54° 25′ lat. S., 57° 32′ long. W. ; profondeur 56 brasses. Deux échantillons.

21 Avril 1904, île Gough ; profondeur 25 brasses. Un seul échantillon.

Les auteurs qui ont étudié en ces derniers temps les Cribrelles antarctiques estiment que les nombreuses espèces qui ont été créées doivent être réunies. LEITPOLDT et MEISSNER pensent que les *Cribrella Pagenstecheri*, *Hyadesi*, *Studeri* et *obesa* ne diffèrent pas des *C. præstans* et *simplex* de Kerguelen, et que toutes ces formes constituent une seule et même espèce, tandis que LUDWIG incline à considérer ces deux dernières espèces comme distinctes des précédentes.

En attendant une révision, qui s'impose absolument, de toutes ces Cribrelles antarctiques, il parait évident maintenant que les différentes formes de la Patagonie et des régions voisines, appartiennent à la même espèce, à laquelle le nom de *Pagenstecheri* doit être appliqué, et qui présente des variations analogues à celles que l'on connait chez la *C. oculata* de l'Atlantique boréal.

Les exemplaires de la *Scotia* rappellent plutôt la forme *Hyadesi* décrite par PERRIER. Dans l'un des individus du banc de Burdwood, $R = 33$ millim. et $r = 8{\cdot}5$ ; les bras sont relativement larges à la base et mesurent 9 à 9·5 millim. Cet individu diffère, à cet égard, du type de PERRIER, qui a les bras plus longs et plus étroits à la base ; mais par les autres caractères, il lui est absolument conforme, notamment en ce qui concerne la disposition des piquants adambulacraires et des plaques latéro-ventrales ainsi que l'armature de ces dernières.

Dans le deuxième individu, $R = 40$ millim. et $r = 8$ millim. ; les bras ont 8 millim. de largeur à la base. La face dorsale rappelle bien la *C. Hyadesi*, et les piquants adambulacraires sont aussi disposés comme dans cette dernière, mais les plaques latéro-ventrales sont plus nombreuses et plus serrées.

Dans le troisième individu, qui provient de l'île Gough, $R = 44$ millim. et $r =$ 8 millim. Les piquants adambulacraires et les plaques latéro-ventrales sont encore disposés comme chez la *C. Hyadesi*, mais les granules qui recouvrent ces dernières tendent à s'allonger en petits piquants. Cette tendance s'accentue sur la face dorsale, qui arrive à offrir la structure indiquée par PERRIER chez la *C. Studeri*, c'est à dire que cette face est formée par des ossicules très serrés portant des piquants très rapprochés et disposés en brosse.

*Cycethra verrucosa* (Philippi).

Voir pour la bibliographie :

MEISSNER, *Hamburger Magalhaensische Sammelreise : Asteroideen*, p. 14.
LORIOL, *Notes pour servir à l'histoire des Echinodermes*, 2e série, fascicule 2, p. 21.
LUDWIG, "Asterien und Ophiuren der schwedischen Expedition nach den Magalhaensländern," *Zeit. f. wiss. Zool.*, Bd. lxxxii., p. 53, pl. vi. fig. 2–3.

1er Décembre 1903, banc de Burdwood, 54° 25′ lat. S., 57° 32′ long. W. ; profondeur 56 brasses. Deux échantillons.

31 Janvier 1904, îles Falkland ; profondeur 5–20 brasses. Un échantillon.

A l'exemple de MEISSNER et de LUDWIG, je considère que la *Cycethra verrucosa* est une espèce très polymorphe dont il n'y a pas lieu de séparer différentes formes qui ont été distinguées sous les noms de *C. electilis*, *simplex*, etc.

Les deux exemplaires du banc de Burdwood rappellent la forme *electilis* Sladen : tout l'ensemble est robuste, les bras sont épais, larges et ils s'amincissent graduellement jusqu'à l'extrémité qui est arrondie. Les plaques ventrales sont très nettement disposées en séries longitudinales et transversales, et elles portent des piquants un peu plus nombreux que ne l'indique SLADEN : il y en a huit à dix par plaque.

Dans le plus grand individu, $R = 52$ millim. et $r = 18$ millim.

L'échantillon des îles Falkland répond bien exactement au dessin et à la description que BELL a donnés de la *C. simplex* : c'est une forme *ganéroïde*, suivant l'expression de PERRIER, sans plaques marginales distinctes.

*Lophaster abbreviatus*, nov. sp. (Pl. IV. fig. 42 et 43.)

18 Mars 1903, 62° 10′ lat. S., 41° 20′ long. W. ; profondeur 1775 brasses. Un seul échantillon.

$R = 11$ millim. ; $r = 5$ millim.

Le disque est épais et renflé. Les bras, très larges à la base, sont assez courts, trapus, triangulaires, avec l'extrémité obtuse. La face dorsale est convexe, la face ventrale est plane.

La face dorsale du disque et des bras est couverte de paxilles peu serrées, irrégulièrement disposées, sauf sur les bras où l'on peut reconnaître quelques rangées longitudinales plus ou moins apparentes. Chaque paxille offre un pédoncule court, épais et trapu, portant des spinules peu nombreuses, au nombre de six à huit seulement : ces spinules sont plus longues que le pédoncule, elles sont dressées ou peu divergentes, subégales ; leur extrémité est rugueuse ou même elle offre quelques denticulations. L'exemplaire qui m'a été remis étant sec, je ne puis distinguer de papules entre les paxilles.

La plaque madréporique est petite, peu distincte, de couleur brune.

Les paxilles des plaques marginales dorsales sont plus développées que les autres :

leur pédoncule est plus long et plus gros, et les spinules sont également plus allongées. Il y a neuf ou dix plaques marginales de chaque côté. Les plaques marginales ventrales correspondent aux dorsales et portent, comme elles, des paxilles bien développées et formant une rangée très apparente. Les deux paxilles qui occupent l'angle interradial sont plus petites que les suivantes.

La face ventrale, réduite à un espace très étroit entre les marginales ventrales et les adambulacraires, est nue.

Les plaques adambulacraires, larges, portent dans le sillon trois piquants divergents, unis par une membrane ; ce chiffre tombe à deux à une certaine distance de la base. Ces piquants sont allongés, cylindriques et amincis ; vus au microscope, ils montrent de fines denticulations à leur surface. Sur leur face ventrale, les plaques adambulacraires offrent un groupe de deux piquants ordinairement parallèles, allongés et forts, qui montrent, au microscope, des denticulations assez marquées.

Les dents sont fortes, proéminentes et allongées. Elles portent, sur leur bord libre, sept ou huit piquants assez courts et coniques, sauf l'interne qui est allongé et cylindrique : je n'en vois pas sur leur face ventrale.

La face dorsale est d'une coloration jaune-brun ; la face ventrale est plus claire.

*Rapports et Différences.*—Evidemment l'individu unique recueilli par la *Scotia* est jeune : il est cependant bien caractérisé et ne peut être confondu avec aucune espèce connue. Il est voisin du *L. stellans* Sladen, dont il diffère surtout par les piquants adambulacraires : le *L. abbreviatus* a trois piquants allongés, tandis que le *L. stellans* a quatre piquants courts et trapus ; les deux piquants ventraux de la première espèce sont aussi plus longs, enfin les dents ne portent pas de piquants sur leur face ventrale. J'ai pu comparer mon échantillon à un *L. stellans* recueilli par la *Belgica*, qui m'a été fort aimablement communiqué par M. le Professeur VAN BENEDEN, et je me suis assuré que les deux espèces étaient bien différentes.

*Solaster Lorioli*, nov. sp. (Pl. IV. fig. 40 et 41.)

7 Mars 1903, 67° 33′ lat. S., 36° 35′ long. W. ; profondeur 2500 brasses. Un échantillon.

$R = 22$ millim. ; $r = 5$ millim.

Le disque est arrondi, peu convexe. Les bras sont étroits à la base et bien distincts du disque ; ils sont allongés, minces et se rétrécissent progressivement jusqu'à l'extrémité qui est obtuse.

La face dorsale du disque et des bras présente des paxilles isolées, composées d'un pédoncule très court, supportant six à huit spinules allongées, minces, cylindriques, à surface un peu rugueuse et se terminant en une pointe irrégulière et denticulée. La

plaque madréporique est indistincte. Les papules sont peu nombreuses. Sur le disque, les paxilles sont disposées sans ordre ; sur les bras, elles deviennent plus petites et forment quelques rangées longitudinales mal définies.

Sur le bord des bras, s'étend une rangée marginale unique de paxilles grandes et fortes qui diffèrent notablement par leur taille des autres paxilles dorsales : leur pédoncule est allongé, épais et cylindrique, et il porte un bouquet d'une douzaine de spinules divergentes. Ces paxilles sont espacées et il n'y en a pas plus de onze à douze le long de chaque bras. La première paxille de chaque série est un peu plus petite. Au microscope, les spinules de ces paxilles ne montrent guère qu'une ou deux denticulations vers l'extrémité, et cette extrémité elle-même se termine parfois par une ou deux dents très fines.

La face ventrale se réduit à un espace triangulaire étroit et nu.

Les sillons ambulacraires sont assez larges et les tubes régulièrement bisériés.

Les plaques adambulacraires portent, dans le sillon, trois piquants allongés, cylindriques et minces ; ce nombre tombe ensuite à deux. La face ventrale de ces plaques constitue une proéminence en forme de tubercule émoussé, muni de quatre et parfois cinq spinules divergentes et disposées en un peigne transversal ; ce nombre tombe ensuite à trois. Tous ces piquants n'offrent de denticulations que vers leurs extrémités.

Les dents sont garnies, sur leur bord libre, d'une demi-douzaine de piquants qui ressemblent aux piquants adambulacraires, mais comme ils sont à peu près tous cassés, il est impossible d'évaluer leur longueur ; je n'en observe pas sur la face ventrale.

*Rapports et Différences.*—Le *S. Lorioli* se distingue facilement de toutes les espèces connues : peut-être l'exemplaire unique recueilli par la *Scotia* n'est pas adulte, mais il est néanmoins très bien caractérisé. Une autre espèce de *Solaster* à cinq bras a été trouvée par la *Valdivia* à l'île Bouvet, à une profondeur de 457 mètres ; l'espèce n'a pas encore été décrite, mais le dessin qu'en donne CHUN montre qu'elle est bien différente du *S. Lorioli*.

### *Solaster australis* (Perrier).

*Crossaster australis*, Perrier, *Mission du Cap Horn : Stellérides*, p. 113, pl. x. fig. 1.
*Solaster australis*, Ludwig, "Asterien und Ophiuren der schwedischen Expedition," *Zeit. f. wiss. Zool.*, Bd. lxxxii., p. 65.

1er Décembre 1903, banc de Burdwood, 54° 25′ lat. S., 57° 32′ long. W. ; profondeur 56 brasses. Trois échantillons.

Les trois exemplaires sont de petite taille, et la longueur de leur grand rayon varie entre 25 et 32 millim. Ils sont donc plus petits que le type de PERRIER auquel ils sont cependant bien conformes. L'un des individus a huit bras et les deux autres en ont neuf.

*Crossaster penicillatus*, Sladen.

SLADEN, *Reports of the "Challenger": Asteroidea*, p. 446, pl. lxx. fig. 5, et lxxii. fig. 9–10.

21 Avril 1904, île Gough ; profondeur 25 brasses. Un échantillon.

$R = 45$ millim.

L'individu est donc plus grand que le type de SLADEN : il est en assez mauvais état, très mou et comme macéré ; les paxilles de la face dorsale sont arrachées, elles ne sont conservées qu'à l'extrémité des bras et sur les bords de ceux-ci ; une partie de la face dorsale est même complètement arrachée. La face ventrale est mieux conservée. Les bras sont au nombre de neuf.

Cet individu est bien conforme au type de SLADEN, qui provenait de Tristan d'Acunha, par une profondeur de 110 brasses.

*Styracaster robustus*, nov. sp. (Pl. IV. fig. 44 et 45.)

9 Avril 1904, 51° 7′ lat. S., 9° 31′ long. W. ; profondeur 2103 brasses. Un seul échantillon en assez bon état de conservation, mais cependant déformé et un peu aplati.

$R = 45$ millim. environ ; $r = 15$ millim. Ces chiffres ne sont qu'approximatifs, les dimensions exactes ne pouvant être évaluées à cause de la déformation de l'exemplaire.

L'ensemble est très robuste ; le disque est haut et épais ; la face ventrale est plane avec les dents saillantes ; la face dorsale offre des plissements qui empêchent de reconnaître sa forme exacte ; les côtés du corps sont plus ou moins profondément excavés. Les bras sont très larges à la base et s'amincissent assez rapidement, tout en restant toujours épais et forts : ils sont cylindriques et se terminent en pointe obtuse.

La face dorsale du disque est couverte de nombreuses paxilles petites, arrondies, subégales, formées par trois ou quatre granules arrondis et bien distincts ; il y en a rarement cinq. La plaque madréporique est assez grande, très rapprochée du bord, dont elle est séparée par trois rangs de paxilles : elle offre à sa surface des sillons divergents.

Les faces latérales du disque sont hautes et verticales. Elles présentent onze organes cribriformes, grands et dont la partie striée est un peu plus large que les espaces intercalaires ; les deux extrêmes sont plus petits que les autres ; ceux-ci renferment chacun une douzaine de rangées d'écailles. Les espaces qui séparent ces organes portent deux ou trois rangs de petits granules arrondis et espacés.

Les plaques marginales dorsales sont au nombre de dix-sept sur chaque bras : six forment les côtés du disque, les onze autres limitent les bras ; la septième est un peu plus large que les suivantes ; toutes sont plus hautes que larges. La dernière plaque, située entre l'avant-dernière et la plaque apicale, est petite et triangulaire. Les plaques des bras sont lisses et n'offrent pas de granules comme celles qui limitent le disque.

Au point de réunion des plaques de la septième et de la neuvième paires, se montrent deux piquants forts et coniques : le premier, toujours plus développé que le second, atteint 5 millim. de hauteur et sa base est très élargie ; il est comprimé latéralement et légèrement recourbé ; le piquant suivant est plus court et simplement conique. Ces deux piquants se montrent constamment sur les cinq bras et il n'en existe pas d'autres.

Les plaques marginales ventrales sont en même nombre que les dorsales, et, sur le disque, elles continuent exactement ces dernières : elles offrent aussi à leur surface les mêmes granulations et sont plus étroites que hautes. Sur les bras, leurs limites verticales ne correspondent pas toujours exactement à celles des plaques dorsales, mais se trouvent parfois reportées un peu plus près du disque : elles sont à peu près carrées et dépourvues de granules. La plaque apicale est peu développée et courte : elle est terminée par un gros piquant, de chaque côté duquel se montre un piquant beaucoup plus petit.

La face ventrale du disque est recouverte d'un tégument épais, sous lequel on ne peut distinguer aucune plaque et qui offre à sa surface des granules arrondis, peu apparents dans la région proximale, mais devenant plus nombreux et plus apparents vers les bords du disque. Les sillons ambulacraires sont assez étroits en dedans du disque et ils s'élargissent sur les bras. Les plaques adambulacraires sont invisibles et cachées sous le même tégument qui recouvre le reste de la face ventrale. On n'aperçoit même pas, dans le sillon, de rangée continue de piquants adambulacraires ; on ne voit, dans les intervalles des tubes ambulacraires, que de petits groupes de deux à quatre granules allongés faisant saillie dans le sillon. Dans la seconde moitié des bras cependant, les granules deviennent plus longs et forment alors des peignes assez distincts de quatre ou cinq piquants. Sur la face ventrale des plaques adambulacraires, en dehors du sillon, se montrent quelques granules peu accusés et qui ne diffèrent pas des autres granules de la face ventrale.

Les dents, saillantes, offrent sur leur bord libre, huit ou neuf petits piquants courts et coniques, qui ressemblent aux granules du sillon ambulacraire, sauf les deux derniers, qui s'allongent et deviennent plus forts, surtout le dernier. A la surface des dents, se montrent plusieurs rangées irrégulières de granules qui deviennent un peu plus forts en dedans, vers l'extrémité proximale de la dent.

*Rapports et Différences.*—Le *St. robustus* se distingue des autres espèces du genre par ses bras très courts et le nombre élevé des organes cribriformes, ainsi que par les caractères de l'armature des plaques adambulacraires. Les espèces de *Styracaster* qui ont les organes cribriformes nombreux (de sept à neuf) ont les bras très longs, comme les *St. horridus* Sladen, et *elongatus* Koehler, tandis que celles qui ont les bras courts, ont des organes cribriformes moins nombreux. Récemment, Ludwig a décrit plusieurs espèces nouvelles de *Styracaster* provenant des dragages de la *Valdivia*, mais aucune de celles-ci n'a de rapport avec le *St. robustus*.

*Hyphalaster Scotiæ*, nov. sp. (Pl. VII. fig. 71 et 72).

18 Mars 1904, 71° 22′ lat. S., 16° 34′ long. W. ; profondeur 1410 brasses. Deux échantillons.

Dans le plus grand individu, $R = 20$ millim., $r = 10$ millim. ; dans le plus petit, $R = 15{\cdot}5$ millim., $r = 8$ millim.

La structure générale est assez robuste. Le disque est épais, et la face dorsale est fortement bombée sur le grand exemplaire ; la face ventrale est un peu convexe ; les bras sont courts, mais épais et forts. Un petit cône épiproctal se montre au milieu du disque sur les deux exemplaires ; il est relativement plus développé dans le petit.

Le disque est grand, avec les côtés à peu près droits. Les bras ne sont pas très larges à la base et ils s'amincissent peu.

La face dorsale du disque est recouverte de paxilles fines, petites et serrées, souvent ovalaires ; chacune d'elles est formée par un piquant central entouré d'une bordure périphérique de six à sept piquants.

La plaque madréporique est petite, ovalaire, avec des sillons divergents ; son bord externe est séparé des plaques marginales dorsales par une seule rangée de granules.

Les plaques marginales dorsales sont au nombre de huit, y compris la dernière. Quatre d'entre elles se trouvent sur les côtés du disque : elles sont plus hautes que larges et lisses. Les autres limitent les côtés des bras et sont contiguës sur la ligne médiane dorsale : la première est grande et large, les deux suivantes sont plus petites, enfin la dernière est extrêmement réduite et triangulaire. Au delà des organes cribriformes, les plaques offrent des granules arrondis assez grands, mais aplatis et espacés.

La face ventrale du disque est couverte de plaques minces, imbriquées, formant des rangées transversales qui deviennent plus étroites à mesure qu'on se rapproche du bord du disque : il y a environ dix rangées de ces plaques. Chacune d'elles porte quelques petits piquants courts, coniques, à pointe émoussée, qui forment, dans leur ensemble, des rangées transversales, naturellement plus serrées dans la région périphérique du disque que dans la région centrale.

Les plaques marginales ventrales sont en même nombre que les dorsales auxquelles elles correspondent, sauf les deux qui suivent les organes cribriformes et qui sont un peu plus courtes. La dernière plaque est quadrangulaire et plus grande que sa correspondante dorsale.

La plaque apicale est assez courte, mais large et renflée du côté dorsal : elle offre un piquant terminal qui n'est pas très développé, et, de chaque côté, un piquant latéral plus petit ; un autre piquant peu important se montre aussi sur sa face dorsale.

Les organes cribriformes sont au nombre de cinq, les trois médians plus larges et les deux autres plus étroits ; l'organe médian renferme une douzaine de rangées d'écailles.

Les sillons ambulacraires sont assez étroits, parfois un peu élargis dans leur région moyenne. Les plaques adambulacraires portent chacune, dans le sillon, trois piquants

assez forts, courts, coniques et pointus. Sur leur face ventrale, on observe deux piquants ayant à peu près les mêmes caractères que les précédents, mais un peu plus forts et plus courts.

Les dents présentent sur leur bord externe une rangée d'une demi-douzaine de piquants identiques aux adambulacraires ; le dernier piquant proximal est plus fort. Vers leur bord sutural, se montre une rangée de trois ou quatre piquants plus courts, et, en dehors de ceux-ci, on peut encore en voir deux ou trois plus petits et inconstants. Les dents forment, en s'adossant, une saillie très marquée : après s'être réunies en dedans, elles s'écartent pour limiter un espace ovalaire, puis se réunissent de nouveau et divergent ensuite assez fortement pour recevoir l'odontophore. Celui-ci est petit, triangulaire, avec un angle proximal aigu et allongé, deux bords latéraux légèrement excavés et un bord distal droit ou légèrement convexe.

Sur l'un des bras, on remarque qu'une des plaques marginales dorsales prend une forme ovoïde et détermine une saillie assez marquée ; aussi l'ordre régulier des plaques se trouve-t-il un peu troublé de ce côté. Cette anomalie est peut-être causée par la présence d'un parasite.

*Rapports et Différences.*—L'*H. Scotiæ* se distingue des autres espèces du genre par ses bras courts et par le nombre des organes cribriformes. L'*H. diadematus* Sladen, dragué entre Valparaïso et Juan Fernandez, qui n'a que cinq organes cribriformes, n'a pas les plaques marginales dorsales contiguës.

*Hyphalaster Scotiæ*, Juv. (Pl. VI. fig. 60.)

Je crois pouvoir rapporter à l'*H. Scotiæ* un très jeune exemplaire d'une Porcellanastéridée recueillie avec les deux individus adultes décrits ci-dessus. Cet exemplaire présente certaines particularités et il ne sera pas inutile d'en donner une description. La taille est très petite : $R = 6$ et $r = 4{\cdot}5$ millim.

Le disque est pentagonal, avec les côtés légèrement excavés. La face dorsale et la face ventrale sont planes et les bords latéraux sont verticaux. Les bras, très courts, sont terminés par une grosse plaque apicale large et épaisse, cordiforme, plus large que longue et échancrée sur son bord proximal. Cette plaque porte un gros piquant dorsal vers son extrémité distale et deux piquants latéraux ; on observe de plus, vers son bord latéral, deux petits piquants qui ressemblent plutôt à des granules coniques.

Vers l'extrémité de l'un des bras, l'exemplaire porte une excroissance qui ressemble beaucoup à une tumeur produite par un parasite et rappelle celles que provoquent les Myzostomes chez les Crinoïdes : pour être certain de cette origine, il aurait fallu disséquer l'échantillon, ce que je n'ai pas osé faire pour ne point le détériorer. Cette tumeur ressemble à celle que j'ai signalée plus haut sur un des *H. Scotiæ* adultes, mais elle est plus marquée. Elle mesure environ un millim. sur deux ; elle est placée obliquement et elle empiète à la fois sur les deux côtés du bras, immédiatement en arrière de la plaque apicale, dont elle a gêné le développement ; elle a également

provoqué sur les deux côtés du bras des anomalies, que j'indiquerai plus bas, dans les plaques marginales et les organes cribriformes.

La face dorsale présente en son milieu un petit cône épiproctal. Elle est recouverte de gros granules, au milieu desquels on distingue un certain nombre de plaques qui ne portent qu'un ou deux granules. Ces plaques sont disposées sans ordre dans la région centrale du disque; sur les bras, elles deviennent plus petites et tendent à se disposer en files radiaires.

La face ventrale du disque est couverte de plaques disposées en rangées transversales, dont la grosseur diminue à mesure qu'on se rapproche des plaques marginales ventrales. On peut distinguer, en dehors des dents, une première rangée proximale de trois plaques, dont la médiane est plus grande et carrée, puis une deuxième rangée de cinq plaques et enfin deux rangées successives de plaques plus petites : cet arrangement n'est d'ailleurs pas absolument constant. Les plaques périphériques portent des granules coniques et pointus au nombre d'un à trois, et ils font généralement défaut sur les plaques proximales.

Les plaques marginales dorsales et ventrales se correspondent exactement et il y en a trois de chaque côté, soit six plaques marginales dorsales et autant de ventrales sur chaque arc entre les plaques apicales. La largeur diminue rapidement de la première à la troisième. Vue par la face dorsale, la première plaque marginale est plus longue que large, la seconde est aussi longue que large et la dernière est plus large que longue : cette dernière est plus large en dedans qu'en dehors; elle n'est pas contiguë à sa congénère, mais se trouve séparée d'elle par deux ou trois rangs de plaques dorsales. Toutes les plaques marginales sont très finement granuleuses.

Les organes cribriformes sont au nombre de trois sur trois des côtés du corps et ce nombre parait être le chiffre normal. Ils sont réduits à deux rangées de papilles situées en face l'une de l'autre et chaque rangée renferme seize à dix-huit granules.

J'ai dit plus haut que l'un des bras portait immédiatement en dedans de la plaque apicale une tumeur dirigée obliquement: cette tumeur n'a pas seulement gêné le développement de la plaque apicale qui est atrophiée de ce côté, mais on doit aussi attribuer à sa présence des modifications dans la disposition des organes cribriformes et des plaques marginales sur les deux côtés de ce bras. D'un côté, il y a quatre organes cribriformes constitués normalement et une plaque marginale supplémentaire : celle-ci est à peu près intacte sur la face ventrale, mais du côté dorsal elle est divisée en deux fragments. Sur l'autre côté, il y a une plaque marginale ventrale supplémentaire près de la plaque apicale, et la deuxième plaque marginale ventrale du même côté s'est divisée en deux plaques superposées. Les organes cribriformes ont la disposition suivante : un médian, normal, qui s'étend jusqu'à la face ventrale ; en dehors vient un organe qui résulte évidemment de la fusion de deux autres et qui affecte la forme d'un U contournant les côtés de la deuxième plaque marginale dorsale, et séparant, par sa branche horizontale, celle-ci et la marginale ventrale. Le troisième, placé en dessous du précédent, a une direction horizontale et sépare les deux moitiés de la plaque marginale ventrale, qui s'est dédoublée.

Les plaques adambulacraires, au nombre de sept, sont deux fois plus longues que

larges. Les premières portent quatre gros piquants, larges et aplatis, à pointe émoussée ; les suivants en ont trois, puis deux seulement. Vers leur bord externe, ces plaques offrent un ou deux granules coniques.

Les dents sont grandes, longues, fortes et elles s'élèvent obliquement jusqu'à leur bord sutural qui est saillant ; elles ne s'écartent l'une de l'autre que vers leur extrémité distale pour recevoir l'odontophore qui est triangulaire et extrêmement réduit. Sur leur bord libre, les dents sont garnies de six piquants qui continuent les piquants adambulacraires auxquels ils sont identiques, sauf le dernier proximal qui est beaucoup plus long ; vers leur bord sutural, on trouve, en outre, deux ou trois granules arrondis.

Ce jeune *Hyphalaster* rappelle beaucoup par son facies, ses caractères et sa taille, le *Pseudaster cordifer* que PERRIER a décrit autrefois comme un genre nouveau et que LUDWIG a montré être un jeune *Thoracaster*. J'ai aussi trouvé, dans les collections de la *Princesse Alice*, un jeune *Thoracaster* à peine différent de l'échantillon décrit par PERRIER. On remarquera que, dans l'exemplaire de la *Scotia*, il n'y a pas de plaque marginale impaire et que ces plaques sont au nombre de trois de chaque côté du bras, tandis que les jeunes *Thoracaster* cités plus haut possèdent la plaque marginale impaire caractéristique.

### *Granaster biseriatus*, Koehler. (Pl. V. fig. 48 et 49.)

KOEHLER, *Expédition Antarctique française du Dr. Charcot : Échinodermes*, p. 11, pl. i. fig. 6, pl. iv. fig. 42.

Novembre 1903, Baie MacDougall, Orcades du Sud ; profondeur 5 brasses. Quelques échantillons.

6 Décembre 1903, Baie de la Scotia, Orcades du Sud ; profondeur 0–2 brasses. Quelques échantillons.

2 Février 1904, Baie de la Scotia ; profondeur 0–2 brasses. Trois échantillons.

Tous ces exemplaires répondent bien au type de l'espèce que j'ai établie d'après les individus recueillis par l'Expédition Charcot. Les bras sont toujours allongés et bien séparés du disque ; les tubes ambulacraires forment deux séries très régulières, parfois avec une légère alternance, et le sillon ambulacraire est étroit. Les piquants adambulacraires sont parfois disposés sur trois rangs, mais cette disposition parait rare et inconstante.

L'examen des exemplaires assez nombreux recueillis par la *Scotia* me confirme donc dans l'opinion, que j'avais exprimée dans mon mémoire sur les Échinodermes de l'Expédition Charcot, à savoir que le *Gr. biseriatus* constituait mieux qu'une simple variété du *Gr. nutrix* et devait être élevée au rang d'espèce.

Je n'ai pu trouver, sur les échantillons de la *Scotia*, la moindre trace de ponte, ni même la moindre indication d'habitudes incubatrices. J'ai ouvert une demi-douzaine d'individus et j'ai observé que les organes génitaux étaient peu développés : dans quelques-uns cependant, j'ai reconnu des œufs.

STUDER a signalé chez le *Gr. nutrix* des pédicellaires droits dans le sillon ambulacraire et des pédicellaires croisés au milieu des granules de la face dorsale, surtout sur les bras.

J'ai retrouvé dans le sillon les pédicellaires droits qui ne sont pas très serrés et je remarque que leurs valves, qui sont terminées par un crochet, offrent bien, comme le dit STUDER, des denticulations vers l'extrémité : mais ces pédicellaires ont un contour différent de ceux que STUDER a représentés chez le *Gr. nutrix* (Pl. V. fig. 48).

Quant aux pédicellaires tridactyles de la face dorsale, ils sont toujours isolés au milieu des granules : ils sont relativement très gros et leur diamètre peut atteindre la moitié de celui des granules : ceux-ci mesurent 0·25 millim. de diamètre et les pédicellaires peuvent avoir de 0·10 à 0·15 millim. Les valves sont finement denticulées sur les bords et très larges. On distingue ces pédicellaires, sous forme de points clairs, au milieu des granules plus gros, sur la fig. 49.

*Zoroaster tenuis* Sladen.

*Reports of the "Challenger" : Asteroidea*, p. 421, pl. lxvii. fig. 1 et 2 ; pl. lxviii. fig. 7 et 8.

13 Avril 1904, 48° 06′ lat. S., 0° 5′ long. W. ; profondeur 1742 brasses. Un seul échantillon.

$R = 19$ millim. ; $r = 4$ millim.

L'unique exemplaire recueilli par la *Scotia* est évidemment un jeune et il est un peu plus grand que le type du *Challenger* dans lequel $R = 15{\cdot}5$ millim. et $r = 2{\cdot}5$ millim. Il n'est pas absolument conforme à la description de SLADEN, mais les différences ne me paraissent pas assez importantes pour nécessiter une séparation spécifique. Ainsi les grands piquants des plaques marginales dorsales et ventrales sont moins développés et ceux des plaques marginales dorsales ne sont pas beaucoup plus grands que les autres piquants, tandis que sur le dessin de SLADEN ces piquants sont grands. La plupart des plaques adambulacraires n'ont que deux piquants au lieu de trois, sauf les premières. Enfin la plaque apicale parait plus grande dans mon exemplaire. J'observe aussi une rangée de plaques latéro-dorsales et latéro-ventrales qui n'existent pas dans l'exemplaire de SLADEN ; ceci tient sans doute à ce que celui-ci est moins développé. Ces différences, comme on le voit, ne sont pas bien considérables.

Le type du *Challenger* provient des parages de la Nouvelle-Guinée, par 2° lat. S. et 144° long. W., et d'une profondeur de 1070 brasses.

*Anasterias cupulifera*, nov. sp. (Pl. V. fig. 52 ; Pl. VI. fig. 58 et 59.)

Avril 1903, Baie de la Scotia, Orcades du Sud ; profondeur 10 brasses. Un échantillon.

$R = 60$ à $65$ millim. ; $r = 11$ millim.

Le disque est petit. Les bras ont environ 15 millim. de largeur à la base et leurs dimensions ne se modifient guère dans leur première moitié ; au delà, ils diminuent progressivement jusqu'à l'extrémité qui est assez pointue.

On aperçoit, sur la face dorsale du disque, un pentagone dont les côtés sont déprimés

et des angles duquel partent des dépressions interradiales qui se continuent jusqu'aux angles interbrachiaux. Ces dépressions correspondent sans doute à l'anneau calcaire et aux branches interradiales qui représentent le squelette dorsal rudimentaire caractéristique des *Anasterias*.

Je ne puis malheureusement donner aucun renseignement sur la structure de ce squelette, pour l'étude duquel il aurait fallu sacrifier l'unique exemplaire que j'avais à ma disposition. Toutefois, la réduction du squelette dorsal, et, par suite, la place de cette Astérie dans le genre *Anasterias*, ne peuvent faire aucun doute : les téguments de la face dorsale, qui sont très minces et transparents, ne laissent pas apercevoir la moindre trace de squelette dans les intervalles que laissent entre elles les pustules spéciales recouvrant cette face. D'ailleurs, l'examen microscopique d'un fragment de la peau ne m'a montré aucune trace d'ossicules calcaires. Les téguments sont très mous et ils se laissent déprimer très facilement, mais ils reprennent de suite leur position primitive, ce qui indique une certaine élasticité.

Les téguments sont recouverts de formations très spéciales, qui correspondent aux pustules des autres espèces d'*Anasterias*, mais qui se présentent avec des caractères tout différents. Pour en faire bien comprendre l'origine, nous allons d'abord considérer la face ventrale de l'animal, en dehors des piquants adambulacraires. Immédiatement en dehors de ces piquants, on trouve une double rangée de piquants disposés d'une manière assez régulière et qui se font face exactement dans chaque rangée. Chaque couple de piquants correspond tantôt à trois, tantôt à quatre piquants adambulacraires. Ces piquants, courts et assez épais, cylindriques, sont, comme d'habitude, entourés d'une collerette renfermant des pédicellaires croisés, mais celle-ci, au lieu de constituer un bourrelet, donne naissance à une série de petits lobes dont chacun renferme un pédicellaire et elle enveloppe la base du piquant en formant une sorte de cupule, à bords irréguliers et frangés, du centre duquel émerge le piquant ; celui-ci est toujours très court et peu apparent. En général, le nombre des pédicellaires que renferme chaque collerette est peu élevé : il y en a dix ou quinze environ et jamais plus de vingt.

A quelque distance au dessus de la rangée externe, on trouve sur les faces latérales du bras une autre rangée de piquants, mais beaucoup moins apparente, moins régulière et moins continue que la précédente, et cette rangée latérale n'apparait qu'à une certaine distance de la base des bras ; les piquants qui la constituent sont aussi plus courts.

En somme, ces dispositions rappellent celles que l'on observe chez d'autres espèces d'*Anasterias*, et notamment celles que j'ai décrites chez l'*A. tenera*. Supposons maintenant que, sur le reste du corps de l'Astérie, les piquants viennent à s'atrophier, mais que les collerettes persistent tout en se rapetissant et en se rapprochant les unes des autres. Nous obtiendrons ainsi les formations qui recouvrent le disque et les bras de notre Astérie, entre les rangées de piquants que je viens de mentionner et qui se présentent comme des expansions de formes très diverses et de dimensions variables (Pl. VI.

fig. 59). Ces expansions sont souvent rendues prismatiques par leur pression réciproque et elles offrent trois ou quatre faces ; leur extrémité libre, élargie, est irrégulièrement lobée et elle est souvent déprimée en son milieu, surtout dans les grandes : cette dépression peut être assez accentuée pour que l'expansion prenne la forme d'une cupule. Enfin, dans les grandes cupules, on voit émerger du centre un petit piquant qui ne dépasse pas les bords de la cupule et qui, le plus souvent, est à peine apparent. Les plus grandes cupules se montrent sur la ligne médiane dorsale des bras, où elles forment une ou deux rangées irrégulières : ces grandes cupules ne se distinguent, en somme, que par une taille plus petite, de celles qui entourent les piquants marginaux que je décrivais tout à l'heure ; elles mesurent un millim. de diamètre. Sur le disque lui-même, on ne distingue pas d'expansions plus grandes que sur les côtés des bras. Bien que ces expansions soient très rapprochées, on peut facilement reconnaître, en les écartant les unes des autres, le tégument mince et transparent sur lequel elles s'implantent : je ne distingue pas de papules dans ces intervalles. Toutes ces expansions restent courtes et leur hauteur, qui ne dépasse pas un millim., est à peu près constante : aussi, elles donnent au toucher la sensation d'un velours grossier.

Dans l'un des interradius, on remarque un espace très restreint où les expansions font défaut et qui indique la position de la plaque madréporique.

Au microscope, les expansions laissent reconnaître un tissu formé de fibres conjonctives très serrées et renfermant quelques pédicellaires croisés dont le nombre se réduit à un seul dans les plus petites et à deux ou trois dans les moyennes ; ces pédicellaires mesurent 0·4 millim. de longueur en moyenne. Dans les cupules plus grandes et qui renferment un petit piquant central, les pédicellaires sont un peu plus nombreux ; de plus, on retrouve, à la base de ces cupules, quelques plaques calcaires réticulées et isolées.

Les sillons ambulacraires sont très larges et les tubes ambulacraires, plutôt grêles, sont disposés sur quatre rangs. Les faces latérales des sillons présentent une rangée de pédicellaires droits assez régulière : ces pédicellaires ne présentent aucun caractère particulier et mesurent 0·6 à 0·8 millim. de hauteur.

Les piquants adambulacraires sont disposés suivant une seule rangée régulière : ils sont petits, allongés, cylindriques, obtus à l'extrémité et recouverts d'une gaine tégumentaire qui est souvent plissée et parait comme lobée à l'extrémité ; ils prennent fréquemment une forme prismatique par suite de leur pression réciproque.

Les dents sont terminées par un grand piquant dirigé obliquement, et, de plus, leur face ventrale porte un piquant identique aux piquants adambulacraires.

La couleur générale est jaunâtre. Il n'y a pas la moindre trace de ponte sur l'exemplaire unique que j'ai en mains.

*Rapports et Différences.*—L'*A. cupulifera* se distingue facilememt des autres *Anasterias* connues par la forme des expansions cutanées qui recouvrent uniformément les téguments et qui sont nombreuses, serrées et souvent en forme de cupules.

*Anasterias tenera*, Koehler.

KOEHLER, *Expédition Antarctique française du Dr. Charcot: Échinodermes*, p. 12, pl. ii. fig. 11 à 16, pl. iii. fig. 27 et 28, pl. iv. fig. 41.

Baie de la Scotia et Baie de Brown, Orcades du Sud; profondeur 10–20 brasses. Quatre échantillons.

Ces exemplaires sont identiques au type que j'ai décrit et figuré; ils sont seulement plus petits: dans le plus grand, $R = 50$ millim., et dans les autres il ne dépasse guère 30 millim. Ces exemplaires offrent, au dessus des deux rangées marginales de grands piquants, la rangée latérale de piquants plus petits et inconstants que j'ai signalée, mais, chose curieuse, cette rangée est mieux marquée et plus constante dans les petits individus que dans les grands.

Le squelette dorsal du disque et des bras est exactement disposé comme je l'ai décrit et il diffère de celui de l'*A. Belgicæ* Ludwig, espèce avec laquelle l'*A. tenera* a le plus d'analogie. J'ai pu examiner les trois espèces d'*Anasterias* recueillies par la *Belgica*, grâce à l'extrême amabilité de M. le Prof. VAN BENEDEN, qui a bien voulu me les communiquer, mais je n'ai naturellement pas pu comparer au squelette de l'*A. tenera* celui de l'*A. Belgicæ*, puisqu'il aurait fallu dessécher et détériorer l'exemplaire. D'ailleurs, la description de LUDWIG est si complète et si claire qu'elle suffit amplement pour toutes les comparaisons.

*Stolasterias Brucei*, nov. sp. (Pl. V. fig. 46 et 47.)

Juillet 1903, Baie de la Scotia, Orcades du Sud; profondeur 10 brasses. Trois échantillons.

Les dimensions respectives des trois exemplaires recueillis sont les suivantes :—

$R = 65$ millim.; $r = 13$ millim.
$R = 85$ „ ; $r = 16$ „
$R = 125$ „ ; $r = 25$ „

Les dimensions du plus grand individu ne sont qu'approximatives, cet individu étant fixé dans l'attitude incubatrice; de fait, il porte une ponte, mais très peu abondante et consistant seulement en une douzaine d'individus qui sont simplement cachés dans la partie proximale des sillons ambulacraires et ne sont rattachés à la mère par aucune production spéciale.

Les deux autres exemplaires ont les bras étalés. J'ai pris comme type l'exemplaire moyen qui est représenté Pl. V. fig. 46 et 47 : c'est chez lui que les caractères spécifiques paraissent le mieux marqués.

Le tégument est épais et les pièces du squelette forment, en dessous de lui, un

réseau comparable à celui que l'on observe chez la *St. glacialis.* Le disque est petit. Les bras sont légèrement rétrécis à leur base qui mesure 14 ou 15 millim., puis ils s'élargissent quelque peu pour atteindre une largeur maxima de 20 millim. (y compris les piquants marginaux) ; ils diminuent ensuite très progressivement jusqu'à l'extrémité qui est en pointe obtuse. Le disque est peu proéminent. La face dorsale des bras est presque plane, avec la ligne carinale légèrement relevée ; leurs faces latérales, étroites, sont verticales.

Vers sa périphérie, le disque présente un cercle de piquants, au nombre d'une quinzaine, courts, cylindriques et obtus, entourés à leur base par une collerette renfermant des pédicellaires croisés ; ces collerettes sont basses, larges et contiguës par leurs bords. Elles limitent ainsi un espace central renfermant un cercle interne d'une dizaine de piquants, plus un piquant central ; tous ces piquants sont plus petits et ils sont entourés d'une collerette aplatie, beaucoup plus basse que celle des piquants externes. De nombreuses papules apparaissent entre les collerettes.

Partant de ce cercle extérieur, la ligne médiane de chaque bras offre une rangée carinale de plaques dont chacune est surmontée par un piquant, court et obtus, entouré d'une collerette contiguë avec les voisines ; aussi ces collerettes se montrent-elles habituellement rectangulaires ou carrées. Cette ligne carinale s'étend jusqu'à l'extrémité des bras : elle n'est pas absolument rectiligne, mais elle offre de légères sinuosités qui se remarquent aussi sur les deux autres exemplaires. Je compte quarante-deux à quarante-trois piquants dans chaque ligne. Les bords du bras offrent une ligne marginale dorsale de piquants identiques aux précédents, mais, toutefois, un peu plus saillants ; leurs collerettes, un peu plus hautes aussi, sont toujours exactement contiguës par leurs bords. Les piquants de cette rangée marginale sont à peu près en même nombre que sur la rangée carinale. Entre ces deux séries, la face dorsale du bras porte de petits piquants très courts, entourés chacun par une collerette très basse et à contours irréguliers, plus petite que sur les rangées marginales et carinale : on peut reconnaître deux ou trois rangées longitudinales, d'ailleurs très irrégulières de ces collerettes. Celles-ci sont séparées par des papules ; de plus, on remarque qu'elles n'atteignent pas la rangée marginale, du moins à la base des bras, et il reste, entre cette rangée et les collerettes, une bande ayant 2 millim. d'épaisseur environ qui n'est occupée que par des papules.

Le petit échantillon présente les mêmes dispositions que celui que je décris. Chez le grand, le disque n'offre pas, à sa périphérie, de cercle de piquants distinct et toute sa surface est uniformément couverte de piquants entourés de collerettes contiguës qui atteignent 3 ou 4 millim. de diamètre. Ces piquants se continuent avec ceux de la face dorsale des bras, mais la rangée carinale y est moins distincte et ses sinuosités sont moins marquées que sur les deux autres individus : les piquants sont à peine plus longs que les autres piquants de la face dorsale et les collerettes sont très aplaties. De chaque côté de cette rangée carinale, on trouve trois ou quatre rangées latérales très irrégulières, et, à la base des bras, il reste toujours entre la rangée la plus externe et la rangée marginale, un espace triangulaire allongé exclusivement occupé par des papules.

En revanche, les piquants de la rangée marginale dorsale sont notablement plus gros et plus forts que les autres et leurs collerettes sont très développées.

Les faces latérales des bras, qui sont verticales, offrent d'abord dans leur région dorsale, une bande dont la hauteur atteint 3 millim. dans l'exemplaire moyen, et 4 dans le grand, et qui est exclusivement occupé par des papules disposées en quatre ou cinq rangées. Dans l'exemplaire moyen, ces papules sont allongées et très serrées, tandis que dans le grand, elles sont contractées et ressemblent à de gros granules qui sont répartis en groupes de huit à douze, dont chacun correspond à une plaque marginale. A la suite de cet espace vient une double série de plaques superposées, dont l'inférieure limite les côtés de la face ventrale. Chaque plaque porte un gros piquant large et aplati, à extrémité obtuse, entouré d'une collerette large et épaisse remplie de pédicellaires croisés. Les piquants des deux séries se correspondent exactement, et, de plus, correspondent aux piquants de la rangée marginale dorsale. La série ventrale est très rapprochée des piquants adambulacraires, et c'est à peine si l'on peut distinguer, à la base des bras, un intervalle étroit, occupé par quelques papules. Les piquants de cette série sont en général un peu plus petits que ceux de la série supérieure, et cette différence, qui est déjà appréciable à la base des bras, s'accentue progressivement ; les piquants deviennent plus courts, leurs collerettes plus basses et plus étroites, et finalement, ils disparaissent vers le quart postérieur des bras. Sur le grand exemplaire, les piquants des deux séries ventrales sont particulièrement épaissis et ils présentent à leur surface des stries plus ou moins profondes qui paraissent même parfois les diviser en un faisceau de trois ou quatre piquants soudés.

Les sillons ambulacraires sont comparativement plus larges dans les deux petits échantillons que dans le grand. Les plaques adambulacraires sont armées d'une double série de piquants gros et forts, aplatis, obtus à l'extrémité et enveloppés d'un tégument qui rend leurs contours un peu irréguliers. Ces piquants sont relativement très développés dans le grand exemplaire où ils sont très aplatis, au moins deux fois plus larges qu'épais. Chaque groupe de trois ou quatre piquants adambulacraires correspond à une plaque marginale.

Les dents sont terminées par deux piquants qui diffèrent à peine des piquants adambulacraires.

Les sillons ambulacraires offrent, sur leurs parois, quelques pédicellaires droits et portés par un pédoncule dépassant leur longueur. Ces pédicellaires, qui ne sont pas très nombreux, sont enveloppés d'une gaine tégumentaire plus ou moins épaisse, et c'est elle qui se prolonge de manière à former le pédoncule. La longueur de ces pédicellaires atteint 1 millim. dans l'échantillon moyen et 1·5 dans le grand.

La couleur de l'échantillon moyen est jaune-brun clair ; les deux autres sont gris-brunâtre.

La *St. Brucei* est incubatrice et j'ai dit plus haut que le grand exemplaire portait une ponte réduite à une douzaine d'individus. Ces jeunes, dont le diamètre varie de 5·5 à 6 millim., sont à un stade extrêmement voisin de celui que j'ai observé chez les

*Anasterias tenera* rapportées par l'Expédition Charcot; ils sont à peine un peu plus avancés. Ils sont simplement placés dans le sillon ambulacraire, près de la bouche de la mère, à laquelle ne les rattache aucun cordon ombilical: ils se détachent d'ailleurs de la mère avec la plus grande facilité; quelques-uns sont restés en place dans le sillon, les autres sont tombés au fond du flacon.

*Rapports et Différences.*—La *St. Brucei* se distingue facilement des autres Astéries antarctiques appartenant au genre *Stolasterias* et qui ne sont qu'au nombre de deux. La *St. eustyla* Sladen, trouvée par le *Challenger* à Tristan d'Acunha, par 100 à 150 brasses de profondeur, possède sur les plaques marginales ventrales une série oblique de trois piquants que n'a pas la *St. Brucei.* Le type de SLADEN est voisin par ses dimensions du petit exemplaire recueilli par la *Scotia*, mais il en est bien différent: il n'offre qu'une seule rangée de piquants latéro-ventraux; les piquants marginaux dorsaux sont plus accentués et il n'y a qu'une seule rangée de plaques entre la rangée marginale dorsale et la rangée carinale; enfin SLADEN n'a pas trouvé dans son espèce de pédicellaires droits. L'autre espèce est la *St. candicans* Ludwig, recueillie par la *Belgica.* Grâce à la complaisance de M. le Prof. VAN BENEDEN, j'ai pu examiner l'exemplaire original, qui est plus petit que le plus petit exemplaire de la *Scotia*, et j'ai constaté qu'il en diffère complètement: les piquants des différentes séries sont fins, coniques, pointus et largement dégagés de leurs collerettes; les piquants adambulacraires sont aussi minces et pointus et les piquants dentaires sont très allongés et minces.

### *Diplasterias Brandti*, J. Bell. (Pl. V. fig. 50 et 51.)

Voir pour la bibliographie:

MEISSNER, *Hamburger Magalhaensische Sammelreise: Asteroideen*, p. 7.

"Shore kelp," îles Falkland. Un seul individu fixé dans l'attitude incubatrice avec le disque très fortement bombé et les bras retroussés en dessus à leur extrémité. La couvée est dissociée et aucun des jeunes n'est resté adhérent à la mère; ceux-ci se trouvent isolés dans le bocal qui en renferme un certain nombre.

1er Décembre 1903, banc de Burdwood, 54° 25′ lat. S., 57° 32′ long. W.; profondeur 56 brasses. Un échantillon dont les dimensions sont: $R = 45$ millim., $r = 12$ millim.

MEISSNER a donné, dans le travail cité plus haut, la synonymie de cette espèce à laquelle se rapportent plusieurs *Diplasterias* de la pointe méridionale de l'Amérique du Sud, et qui avaient été considérées par les auteurs comme constituant des espèces distinctes. J'estime que l'on doit également réunir à la *D. Brandti*, au moins deux des *Diplasterias* de la mission du Cap Horn décrites par PERRIER: la *D. Loveni* et la *D. Lütkeni.* J'ai pu étudier les exemplaires de la première espèce qui se trouvent au Jardin des Plantes et son identité avec la *D. Brandti* ne fait aucun doute pour moi. Quant aux nombreux échantillons de *D. Lütkeni* que la mission du Cap Horn a

recueillis, il a été impossible, malgré les recherches que M. le Prof. JOUBIN a bien voulu faire dans les collections du Muséum, d'en retrouver un seul exemplaire. D'après PERRIER qui a créé cette espèce, elle est très voisine de la *D. Loveni*, et en comparant sa description à celle des différentes espèces qui doivent être réunies à la *D. Brandti*, je ne vois pas de caractère qui permette vraiment de la séparer de cette espèce évidemment polymorphe.

En ce qui concerne la *D. spinosa*, Perrier, qui provient également de la mission du Cap Horn, je ne pourrais être aussi affirmatif. Il est certain qu'elle offre un facies assez différent des échantillons de *D. Brandti* que j'ai pu examiner et ses caractères ont été bien indiqués par PERRIER, mais, en somme, je n'ai pu voir, sur l'exemplaire original, de caractères bien importants qui permettent de la séparer nettement de la *D. Brandti*. Toutefois, je n'ose me prononcer à ce sujet, car le nombre des exemplaires de cette dernière espèce que j'ai eus en mains est trop peu élevé pour que j'aie pu me faire une idée exacte de la valeur des variations qu'elle peut présenter.

Je n'ai pas à revenir ici sur les caractères de la *D. Brandti*, dont il existe de bonnes descriptions et des dessins suffisants, soit sous le nom de *D. Brandti*, soit sous ceux de *D. Belli* Studer, *glomerata* Sladen, et *neglecta* Bell. Je me contente de représenter ici l'individu qui était accompagné de sa couvée (Pl. V. fig. 50), mais il me parait utile de décrire les caractères de ces jeunes.

Ainsi que je l'ai dit plus haut, aucun de ceux-ci n'était en place et tous se trouvaient au fond du bocal renfermant leur mère, mais, lorsqu'ils étaient en vie, ils étaient certainement fixés à celle-ci comme PERRIER les a représentés chez l'*A. spirabilis* (*A. antarctica*) et comme LUDWIG et moi l'avons vu chez diverses *Anasterias*. Tous les jeunes montrent, en effet, dans un des interradius de la face ventrale, l'extrémité d'un court pédoncule brisé. Presque tous sont isolés, sauf une dizaine qui forment un petit groupe fixé sur un cordon commun.

Comme d'habitude, ces jeunes individus sont tous au même stade de développement ; ils sont de très petite taille, leur diamètre total ne dépassant pas 2 millim. (Pl. V. fig. 51). Le corps a la forme d'un pentagone à côtés un peu excavés et les bras sont encore peu marqués. La hauteur est presque égale au diamètre, car la face dorsale est fortement renflée : le corps est en effet rempli par une masse compacte de vitellus. La présence d'un vitellus aussi abondant laisse supposer que le jeune ne reçoit de sa mère qu'une faible partie des matériaux qui lui sont nécessaires pour la formation de ses tissus et que le cordon ombilical ne sert guère que comme organe de suspension.

J'ai étudié ces jeunes exemplaires à l'aide de coupes qui ne montrent rien de nouveau et à l'aide de préparations *in toto* obtenues en éclaircissant les objets à l'huile de cèdre et au baume de Canada. En raison de l'épaisseur des tissus et de l'opacité du vitellus, ces préparations ne sont jamais bien transparentes, sauf sur les bords : elles permettent cependant de se rendre compte de la disposition des plaques calcaires qui sont encore à un stade très jeune et se présentent sous forme de minces plaques réticulées et toujours isolées les unes des autres.

En examinant une de ces jeunes Astéries du côté ventral (Pl. V. fig. 51), on voit partir, à une certaine distance du centre et dans la direction de chaque bras, une double rangée de plaques très minces et réticulées. Les plaques de chaque rangée se correspondent exactement et forment ainsi des paires : on remarque que les plaques des deux premières paires sont plus écartées que les suivantes et celles-ci se continuent jusqu'à l'extrémité du bras. Les plaques proximales sont plus grandes que les autres, dont les dimensions diminuent progressivement, et les quatre ou cinq dernières sont particulièrement amincies. Je compte une douzaine de plaques dans chaque rangée ; les deux ou trois dernières sont placées de chaque côté de la plaque terminale du bras. Ces plaques représentent évidemment les ambulacraires. Beaucoup plus en dehors, et près du bord du bras, on peut voir une autre rangée de plaques situées les unes derrière les autres et assez bien alignées, mais irrégulières comme taille. Ces plaques ne correspondent pas encore aux précédentes ; elles représentent sans aucun doute les plaques adambulacraires.

Enfin, à l'extrémité de chaque bras, se montre une grande plaque arrondie et bien distincte : c'est la plaque terminale.

Du côté dorsal, on ne distingue, dans la région centrale du disque, que quelques plaques peu nombreuses, disposées sans aucun ordre et à une certaine distance du centre : leur nombre varie de une à quatre.

L'état de conservation des tissus ne m'a pas permis d'entreprendre des recherches plus approfondies sur la structure de ces jeunes Astéries.

### *Diplasterias Turqueti*, Koehler.

KOEHLER, *Expédition Antarctique française du Dr. Charcot : Échinodermes*, p. 19, pl. ii. fig. 17, pl. iv. fig. 39.

Juin 1903, Baie de la Scotia, Orcades du Sud ; profondeur 18–20 brasses. Deux échantillons.

Avril et Décembre 1903, Baie de la Scotia et Baie de Brown, Orcades du Sud ; profondeur 9–10 brasses. Cinq échantillons.

Tous ces individus sont plus petits que le type que j'ai décrit : dans le plus grand, $R = 57$ millim., et dans le plus petit, $R = 25$ millim.

Dans le plus grand exemplaire, la face dorsale des bras offre des piquants plus nombreux que dans les autres et que dans les échantillons recueillis par le Dr. CHARCOT : ces piquants tendent même à former des rangées longitudinales, très irrégulières d'ailleurs ; l'on peut distinguer une rangée médiane et deux rangées latérales, et, en dehors de ces dernières, viennent encore quelques piquants isolés.

Dans le plus petit exemplaire, les deux rangées marginales ventrales de piquants n'existent pas toujours, et, en certains points, on ne peut distinguer qu'une seule rangée.

*Diplasterias induta*, nov. sp. (Pl. VII. fig. 68 à 70.)

Juin 1903, Baie de la Scotia, Orcades du Sud ; profondeur 10–20 brasses. Un seul échantillon.

$R = 12$ millim., $r = 9$ millim. Les bras mesurent environ 10 millim. de largeur à la base, sans compter les piquants marginaux, et 13 en comptant ces piquants ; ils s'amincissent très lentement dans les deux premiers tiers, et un peu plus rapidement dans le dernier tiers jusqu'à l'extrémité qui se termine en pointe obtuse. Le disque est de moyenne grosseur.

Les côtés des bras sont limités, sur la face dorsale, par une rangée de piquants, au nombre de trente-cinq à trente-huit, aplatis, terminés par une extrémité arrondie et faisant une saillie de 0·5 millim. environ hors d'une collerette qui rappelle parfois la forme d'un cornet entourant la base du piquant et renfermant quelques pédicellaires croisés. Tout le reste de la face dorsale du disque et des bras est couvert d'expansions verticales, ressemblant à celles que j'ai décrites plus haut chez l'*Anasterias cupulifera*, mais, en général, plus fines, plus serrées et offrant moins fréquemment et moins nettement la forme de cornets que dans cette dernière espèce : ces expansions sont d'ailleurs très inégales et elles sont souvent aplaties par pression réciproque. En certains points, surtout sur le disque, ces expansions se relient les unes aux autres par des trabécules de manière à former une sorte de tissu spongieux ou bien à constituer un ensemble méandrinoïde (Pl. VII. fig. 70). Il est rare de trouver, au milieu de ces expansions, un petit piquant. Elles sont très serrées et les interstices qu'elles laissent entre elles sont occupés par des papules. L'ensemble donne au toucher la sensation d'un velours un peu rude. Le tégument sous-jacent est très rigide et il ne se laisse pas déprimer. En examinant au microscope une portion du tégument de la face dorsale, on aperçoit par transparence, en dessous des téguments, un réseau calcaire formé par de petits ossicules deux ou trois fois plus longs que larges et limitant des mailles irrégulières.

Dans l'un des interradius, et tout près du bord du disque, on reconnait un espace arrondi qui est occupé par la plaque madréporique : celle-ci est nue et offre à sa surface des sillons divergents à partir du centre : elle n'est entourée d'aucune formation particulière. Vers le centre du disque, on distingue un autre espace nu, au milieu duquel s'ouvre l'anus, qui est très petit et apparait comme un pore très fin.

Les côtés des bras, sur la face ventrale, montrent une double série de plaques qui portent chacune un piquant entouré d'une expansion tégumentaire renfermant plusieurs pédicellaires croisés ; les piquants de la rangée supérieure correspondent exactement aux piquants de la rangée inférieure et cette double rangée correspond elle-même à une rangée latéro-dorsale qui occupe les côtés de la face dorsale des bras ; seulement les premiers sont plus forts, plus larges et plus longs que les piquants latéro-dorsaux. Entre les deux rangées de piquants latéro-ventraux, se trouve, sur les côtés des bras, un espace étroit et mesurant à peine 2 millim. de largeur à la base des bras : cet espace est surtout occupé par des papules, avec quelques expansions cutanées très minces.

Les piquants adambulacraires sont très régulièrement disposés en deux rangées égales :

ils sont de moyenne longueur, aplatis, avec l'extrémité obtuse et entourés d'un mince tégument qui rend leurs contours un peu irréguliers.

Le sillon ambulacraire est très large. Les tubes ambulacraires sont minces et très régulièrement quadrisériés. Sur les bords du sillon, on remarque, de chaque côté, une rangée de pédicellaires droits qui ne présentent rien de particulier.

Chaque dent est terminée par un piquant qui ne diffère guère des piquants adambulacraires.

*Rapports et Différences.*—La *D. induta* est voisine de la *D. Turqueti* Koehler, dont elle se rapproche par l'absence de piquants sur la face dorsale du disque et des bras, mais ici les expansions cutanées, au lieu de constituer des pustules basses et élargies, sont élevées, minces, souvent élargies, comprimées par pression réciproque, de grosseur variable et se présentant parfois sous forme de cornets.

Par son facies extérieur, la *D. induta* rappelle absolument l'*Anasterias cupulifera* décrite plus haut (p. 566). Il est très curieux de voir que certaines espèces d'*Anasterias* et de *Diplasterias* antarctiques ont absolument le même habitus extérieur, quoique ces deux genres aient une structure interne bien différente. J'ai déjà signalé que la *Diplasterias Turqueti* et l'*Anasterias tenera*, toutes deux découvertes par l'Expédition Charcot, avaient un facies identique. Nous constatons maintenant que la *Diplasterias induta* présente la même apparence extérieure que l'*Anasterias cupulifera*. Ces deux espèces ont d'ailleurs été capturées par la *Scotia* dans la même station.

### *Asterias antarctica* (Lütken).

Voir pour la bibliographie :

Leitpoldt, "Asteroidea der Vettor-Pisani Expedition," *Zeit. f. wiss. Zool.*, Bd. lix., p. 70 (*Asterias rugispina*).
Meissner, *Hamburger Magalhaensische Sammelreise : Asteroideen*, p. 10.
Loriol, *Notes pour servir à l'histoire des Échinodermes*, 2° série, fasc. 2, p. 36.
Ludwig, "Asterien und Ophiuren der schwedischen Expedition," *Zeit. f. wiss. Zool.*, Bd. lxxxii., p. 70.

Une quinzaine d'échantillons recueillis en différentes localités des îles Falkland, à des profondeurs ne dépassant pas 6 brasses.

Les auteurs ont déjà indiqué les différences que peuvent présenter, dans leur développement, le squelette dorsal du disque et des bras, ainsi que les piquants, et ces différences avaient amené la création de plusieurs espèces qui ne peuvent être maintenues. Dans le travail cité plus haut, Meissner a représenté les deux formes extrêmes que l'on peut observer : l'une avec un squelette dorsal et des piquants très développés et l'autre avec un squelette très réduit.

Les exemplaires de la *Scotia* se rapportent à cette dernière forme : ils ont le squelette plus ou moins réduit et les piquants sont toujours très courts, peu ou même pas du tout visibles extérieurement et peu nombreux. La face dorsale des bras est molle et beaucoup de ces échantillons ressemblent à des *Anasterias*. Mais la dessiccation ou un traitement très délicat à la potasse, permettent toujours de reconnaître les mailles calcaires du réseau dorsal.

*Asterias pedicellaris*, nov. sp. (Pl. VII. fig. 61 à 67 ; Pl. VIII. fig. 74 à 78.)

18 Mars 1904, 71° 22′ lat. S., 16° 34′ long. W. ; profondeur 1410 brasses. Cinq échantillons.

Dans le plus grand exemplaire, $R = 40$ millim. et $r = 7$ millim. ; dans deux autres, la longueur de $R$ varie de 25 à 28 millim. ; trois autres enfin sont beaucoup plus petits et leurs grands rayons mesurent respectivement 15, 12 et 7 millim. Il y a en outre quelques bras isolés. Je décrirai le plus grand individu.

Les bras sont subégaux, mais l'un d'eux est cassé vers le milieu. Le disque est petit, assez bombé sur la face dorsale ; les bras, allongés, sont étroits à la base qui mesure environ 5 millim. de largeur et diminuent peu à peu de largeur jusqu'à l'extrémité qui est assez pointue ; leur face dorsale est convexe.

Le squelette dorsal des bras forme trois rangées longitudinales de plaques assez régulières et réunies par des bandes transversales de manière à laisser entre elles de grandes mailles rectangulaires un peu plus larges que longues. La rangée médiane forme une saillie assez marquée, les deux autres limitent les bords latéraux de la face dorsale du bras. Au point de réunion des plaques, se montrent des piquants allongés, minces, coniques et pointus ; ces piquants sont toujours isolés. Il m'a été absolument impossible de retrouver à la base de ces piquants la moindre indication d'une gaine de pédicellaires. Parfois, comme je le remarque sur l'un des bras chez un individu de taille moyenne, la rangée médiane de plaques se dédouble sur une certaine longueur et l'on observe en même temps deux rangées de piquants. Les papules sont peu nombreuses et isolées.

Sur le disque, les plaques forment un cercle irrégulier d'une dizaine de plaques portant chacune un piquant : on distingue ordinairement cinq piquants radiaux et cinq autres piquants interradiaux un peu plus petits. En dedans de ce cercle, on trouve un réseau de plaques portant quatre ou cinq piquants. La plaque madréporique est petite et peu distincte.

En certains points de la face dorsale des bras, on remarque quelques pédicellaires croisés vraiment énormes, dont la longueur peut dépasser 2 millim. sur 1 de largeur : leur présence donne à la face dorsale de l'*A. pedicellaris* un facies particulier. Ces pédicellaires ne paraissent constants, ni comme nombre ni comme situation. Ils sont disséminés en nombre variable à la face dorsale des bras, mais toujours isolés et peu nombreux : ils sont parfois plus fréquents vers l'extrémité des bras et peuvent aussi se montrer sur le disque. Je les rencontre déjà sur les petits individus qui en offrent deux ou trois sur chaque bras. En somme, ces pédicellaires, isolés et énormes, remplacent les pédicellaires croisés qui sont groupés en une collerette à la base de chaque piquant dans le genre *Asterias* et qui font défaut ici. Ces pédicellaires ont la même structure que ceux qui se trouvent à la base des piquants ventraux : j'y reviendrai ci-dessous.

La face ventrale des bras est limitée par une rangée latérale de plaques qui correspondent exactement aux plaques latéro-dorsales. Chaque plaque porte un piquant

identique à ceux de la face dorsale, mais ce piquant offre à sa base un petit groupe de six à dix pédicellaires croisés qui forment par leur ensemble une collerette analogue à celle qu'on connait chez les autres *Asterias*.

L'espace étroit qui reste libre entre les plaques marginales ventrales et les adambulacraires n'offre pas de plaques distinctes, mais seulement quelques pédicellaires croisés identiques à ceux qu'en observe à la base des piquants marginaux. Ces pédicellaires ont la même structure que ceux de la face dorsale, mais ils sont beaucoup plus petits et ils n'atteignent que 0·5 à 0·6 millim. de longueur.

Les piquants adambulacraires, disposés sur une seule rangée, sont très longs, cylindriques, légèrement renflés à la base et terminés par une extrémité obtuse.

Les sillons ambulacraires sont assez larges et les tubes ambulacraires forment quatre rangées, mais ils sont souvent alternes de chaque côté. On remarque sur les bords quelques pédicellaires droits assez rares, dont la structure ne présente rien de particulier.

Les pédicellaires croisés de la face ventrale et les pédicellaires beaucoup plus gros qui sont disséminés sur la face dorsale, offrent, dans leur structure, certaines particularités (Pl. VII. fig. 62 à 66 ; Pl. VIII. fig. 75 à 78). Leurs valves vont en s'amincissant jusqu'à l'extrémité qui se termine par un crochet plus fort et plus apparent sur les petits pédicellaires des piquants ventraux que sur ceux de la face dorsale. Ces valves sont creuses et en forme de cornets : leurs bords affrontés sont munis de denticulations inégales, moins nombreuses et moins développées dans les gros que dans les petits où elles s'enchevêtrent les unes dans les autres. Enfin le tissu calcaire des valves est beaucoup plus fin et les mailles sont plus serrées dans les gros pédicellaires de la face dorsale que dans ceux de la face ventrale. Un mince tégument enveloppe ces pédicellaires.

La couleur générale des échantillons est gris-jaunâtre.

*Rapports et Différences.*—L'*A. pedicellaris* se distingue de toutes les autres espèces connues par la grosseur et les caractères particuliers des pédicellaires croisés de la face dorsale, qui se montrent isolés et en nombre restreint sur cette face.

### *Freyella Giardi*, nov. sp. (Pl. VI. fig. 53 à 57.)

7 Mars 1903, 67° 33′ lat. S., 36° 35′ long. W. ; profondeur 2500 brasses. Un disque dépourvu de bras et un autre disque portant un seul bras adhérent, plus un certain nombre de bras séparés.

21 Mars 1904, 69° 33′ lat. S., 15° 19′ long. W. ; profondeur 2620 brasses. Deux exemplaires, dont l'un a conservé trois bras complets et l'autre quatre ; il y a en outre un certain nombre de bras détachés.

La plupart des bras sont contournés et repliés, leurs piquants marginaux sont ordinairement cassés : les échantillons paraissent avoir été fortement comprimés et endommagés par les appareils de dragage et les filaments des fauberts.

Le diamètre du disque varie, suivant les individus, de 8 à 9 millim. Les bras sont extrêmement longs et ils peuvent avoir jusqu'à 15 centim. de longueur, ce qui fait que le rapport $R/r$ atteint la valeur de 15 ou 20.

Le disque est arrondi, légèrement déprimé sur la face dorsale et un peu excavé entre les bases des bras. Ceux-ci sont au nombre de six. Ils s'insèrent sur le disque par une base étroite, puis s'élargissent et se renflent sur une longueur de 2 à 4 centim. ; il est impossible de fixer exactement la longueur de cette région génitale, qui se continue avec le reste du bras sans ligne de démarcation définie. La longueur maxima de la région génitale est de 4·5 millim. ; au delà, les bras ont 3 millim. de largeur, puis ce chiffre tombe à 2·5, 2 et 1·5.

La face dorsale du disque est couverte de plaques inégales, polygonales ou arrondies, contiguës par leurs bords et sans la moindre trace d'imbrication. Chacune d'elles porte un piquant fort, conique, allongé et pointu, dont la longueur dépasse la largeur de la plaque ; il est rare de trouver deux piquants sur la même plaque. Beaucoup de ces piquants sont cassés. Sur la plupart d'entre eux, on reconnait une couronne de pédicellaires croisés, ordinairement placée à une certaine distance de la base. Cette couronne ne se montre pas sur tous les pédicellaires, mais il est possible qu'elle ait été arrachée accidentellement, car, ainsi que je l'ai dit plus haut, les échantillons sont fortement endommagés. En outre, les plaques du disque présentent à leur surface quelques pédicellaires isolés qui ne sont pas nombreux.

Sur les faces latérales du disque, et dans chaque espace interradial, on observe une plaque ovalaire impaire, allongée verticalement et dont la surface est finement granuleuse. Cette pièce sépare en bas les extrémités distales des deux dents de chaque paire : elle offre les mêmes rapports que chez la *F. sexradiata* Perrier, et la *Belgicella racovitzana* Ludwig.

L'anus, légèrement excentrique, est très petit. La plaque madréporique, très grosse, est située très près du bord du disque et offre un sillon sinueux, limité par deux lèvres très proéminentes et le plus souvent brisées.

Les plaques dorsales du disque se continuent sur les bras, mais elles deviennent beaucoup plus grandes tout en conservant les mêmes caractères : elles sont polygonales, contiguës, inégales et disposées sans ordre : il y en a à peu près six ou sept sur une même ligne transversale. Sur les côtés du bras, les plaques inférieures s'appuient sur les pièces adambulacraires et leur bord libre déborde même ces pièces sans contracter d'adhérence avec elles. Chaque plaque porte, en son centre, un gros piquant allongé, conique et pointu, souvent brisé et offrant, à une certaine distance de sa base, une couronne large et assez lâche de pédicellaires croisés ; en outre, les plaques offrent à leur surface quelques pédicellaires isolés.

La région génitale possède donc, sur sa face dorsale, un squelette bien développé et compact, mais ce squelette ne reste pas limité à cette région et il se continue bien au delà sur la partie rétrécie des bras : seulement les plaques deviennent progressivement plus petites. Quatre ou cinq centim. au delà de la portion élargie, les plaques, qui jusqu'alors étaient restées contiguës, commencent à se séparer les unes des autres,

et, en même temps, elles disparaissent sur les côtés des bras. On peut souvent distinguer quatre rangées irrégulières de plaques inégales: deux de chaque côté de la ligne médiane et deux latérales; puis les plaques disparaissent peu à peu et le piquant persiste seul. Cependant on peut retrouver des plaques jusqu'au voisinage de l'extrémité du bras.

Les plaques adambulacraires sont allongées, très fortement excavées dans leur région médiane par les pores ambulacraires correspondant; elles sont élargies aux extrémités et s'articulent les unes avec les autres par des facettes larges, aplaties et légèrement obliques; la facette antérieure est à peu près plane, tandis que la facette postérieure offre une apophyse interne dirigée obliquement et qui contourne la facette antérieure de la plaque suivante. Je n'ai pas pu découvrir sur ces plaques de piquants dans le sillon ambulacraire, sauf sur quelques plaques de la région génitale dans l'exemplaire dont trois bras étaient conservés; partout ailleurs ces piquants manquaient, mais il est évident qu'ils devaient exister, tout au moins dans la région proximale des bras, et qu'ils ont été arrachés. Vers le milieu de leur face ventrale, les plaques adambulacraires sont munies d'un gros piquant fort, épais et pointu et dont la longueur atteint à peu près celle de la plaque adambulacraire; l'insertion de ce piquant se rapproche plus ou moins de l'extrémité distale. Ces piquants sous-ambulacraires sont enveloppés d'une gaine de pédicellaires qui recouvre presque toute leur longueur. A la base du bras, la première plaque adambulacraire porte en outre, vers son bord distal, un autre piquant analogue au précédent, conique, pointu et dirigé obliquement en dedans.

Les plaques adambulacraires portent de plus, sur leur face externe et vers leur bord distal, un gros piquant dirigé en dehors et qui apparait vers la troisième ou la quatrième plaque et s'insère au dessus du piquant sous-ambulacraire. Ce piquant se montre généralement de deux en deux articles, mais avec quelque irrégularité, et, à une certaine distance de la base du bras, on peut l'observer sur presque tous les articles. Il devient plus long que l'article et il est entouré, comme d'habitude, par une gaine de pédicellaires croisés.* Ce piquant s'articule sur un gros mamelon porté par la face latérale de la plaque adambulacraire. Il correspond évidemment au piquant marginal des autres Brisingidées et qui est ordinairement porté par l'initiale des arceaux; mais ici, il n'y a pas la moindre trace d'arceaux ni d'initiales d'arceaux et le piquant s'insère directement sur la plaque.

La plaque terminale des bras est plus longue que large, et elle porte à son extrémité deux piquants latéraux et un piquant médian un peu plus grand.

Les dents sont allongées, largement séparées l'une de l'autre. Elles portent sur leur bord proximal ou buccal, qui est étroit, deux piquants: l'interne gros, fort et allongé, l'externe plus fin et plus court. Sur le bord externe, chaque dent offre deux piquants. Tous ces piquants sont entourés d'une gaine tégumentaire bourrée de pédicellaires.

Les organes génitaux se prolongent 2 ou 3 centim. au delà de la région génitale. A la base du renflement, on trouve, à côté des tubes génitaux, deux cœcums intestinaux ayant 1 centim. de longueur environ.

La coloration générale est gris-clair.

* Cette gaine n'a pas été représentée sur les fig. 54, 55 et 56 faites d'après des échantillons desséchés.

*Rapports et Différences.*—La *F. Giardi* est voisine de la *F. sexradiata* Perrier: elle en diffère par la présence, sur la face dorsale des bras, de plaques formant un revêtement continu qui dépasse de beaucoup la région génitale; les bras sont aussi très développés et sans doute beaucoup plus longs que chez la *F. sexradiata*. Quant à l'armature des plaques adambulacraires, je ne puis pas invoquer, pour séparer les deux espèces, l'absence de piquants dans le sillon chez la *F. Giardi*, car je ne suis pas sûr que ces piquants, que j'ai vus sur certains articles proximaux, n'existent pas aussi plus loin.

### *Belgicella racovitzana*, Ludwig. (Pl. VII. fig. 73.)

*Résultats du Voyage du S.Y. "Belgica"*: Ludwig, "Die Seesterne," p. 59, pl. iv. fig. 40–44, pl. v. fig. 45–51.

18 Mars 1904, 71° 22′ lat. S., 16° 34′ long. W.; profondeur 1410 brasses. Deux échantillons.

Dans l'un des exemplaires, le disque a un diamètre de 10 millim. Quatre bras sont adhérents au disque; l'un d'eux, très court, est en voie de régénération et sa longueur n'atteint pas 1 centim. La plaque terminale, relativement petite, est quadrangulaire et son bord distal porte trois spinules fines et égales.

Dans l'autre exemplaire, le diamètre du disque est de 11 millim. et quatre bras sont conservés. Ces bras ont environ 4 millim. de largeur à la base, puis, trois ou quatre millim. au delà de leur insertion, ils commencent à s'élargir et atteignent rapidement 6·5 millim., ensuite ils diminuent lentement de largeur: la longueur de la région génitale, comptée à partir de la base du bras, est d'environ 25 millim. Les bras ne doivent pas être très longs et l'un d'eux mesure 8 centim. J'ai représenté la face dorsale grossie de cet exemplaire.

Grâce à l'obligeance de M. le Prof. van Beneden, qui a bien voulu me le communiquer, j'ai pu comparer l'exemplaire original de la *Belgica* aux échantillons de la *Scotia* et j'ai constaté leur identité. J'ai peu de choses à ajouter à la description si complète de Ludwig. Je remarque seulement que sur mes exemplaires, la plaque centro-dorsale est un peu plus petite que les interradiales et que celles-ci sont plus rapprochées du bord du disque que sur le dessin de Ludwig; de plus, elles s'infléchissent nettement sur les faces latérales du disque. J'ai d'ailleurs pu observer sur le type de la *Belgica*, que ces plaques sont plus rapprochées de la périphérie que ne l'indique Ludwig; elles sont aussi un peu ovalaires, tandis qu'elles sont circulaires sur le type. Enfin, les piquants adambulacraires des quatre ou cinq premières paires ne sont pas terminés en pointe, mais ils sont légèrement renflés à l'extrémité et ils offrent de petits lobes séparés par des stries plus accentuées que sur le reste du piquant; ensuite les piquants deviennent progressivement pointus. Ludwig n'a pas indiqué cette disposition que j'ai observée sur le type, dont beaucoup de piquants proximaux sont d'ailleurs cassés.

## OPHIURES.

*Ophioglypha Brucei*, nov. sp. (Pl. VIII. fig. 81 et 82.)

10 Mars 1903, 66° 40′ lat. S., 40° 35′ long. W. ; profondeur 2425 brasses. Un échantillon.

13 Mars 1903, 64° 48′ lat. S., 44° 26′ long. W. ; profondeur 2485 brasses. Cinq échantillons.

21 Mars 1904, 69° 33′ lat. S., 15° 19′ long. W. ; profondeur 2620 brasses. Deux échantillons.

Dans le plus grand exemplaire, le diamètre du disque est de 14 millim. et les bras ont 38 millim. de long ; dans deux autres, le diamètre du disque atteint respectivement 13 et 11 millim. ; les autres individus sont plus petits et le diamètre de leur disque varie entre 9 et 4 millim.

Le disque est mince et aplati, à contour pentagonal. Les bras sont fins et grêles.

Les contours des plaques dorsales du disque sont un peu obscurcis par le tégument : elles sont polygonales-arrondies et inégales. On reconnait une rosette de six plaques primaires, grandes et arrondies, la centro-dorsale de même taille que les radiales et séparée d'elles par une ou deux rangées de petites plaques. Il existe, en général, dans les espaces interradiaux, deux plaques plus grandes que les voisines, dont la dernière occupe le bord du disque. Entre ces différentes plaques, le reste du disque est occupé par des plaques plus petites, irrégulières et polygonales. Les boucliers radiaux sont très grands, triangulaires, plus longs que larges et séparés sur toute leur longueur par une rangée de plaques rectangulaires ou carrées, dont la dernière est parfois assez grande ; ils sont divergents et leur longueur est supérieure au tiers du rayon du disque. En dehors des boucliers radiaux, de chaque côté de la base des bras, il existe quelques petites plaques arrondies, mais on ne peut découvrir la moindre trace de papilles radiales.

La face ventrale offre des plaques très inégales, polygonales-arrondies. Les plaques génitales sont allongées et minces. Les fentes génitales sont extrêmement étroites et courtes, peu apparentes, et elles sont limitées aux côtés de la première plaque brachiale latérale : elles se présentent sous forme de fentes très étroites, limitées par deux bords parallèles très rapprochés, sans la moindre trace de papilles.

Les boucliers buccaux sont assez grands, un peu plus larges que longs, triangulaires ou plutôt trifoliés, la région proximale formant un lobe arrondi et obtus ; les côtés sont légèrement excavés et se continuent, par un bord externe largement arrondi, avec le bord distal qui est à peu près droit, ou parfois légèrement excavé. Les plaques adorales sont allongées, élargies dans leur région moyenne qui se moule sur la concavité des boucliers

buccaux et rétrécies vers leurs extrémités, surtout en dehors ; elles sont contiguës en dedans. Les plaques orales sont triangulaires, grandes et hautes. Les papilles buccales latérales sont petites, basses, rectangulaires et elles forment une bordure à peu près continue, dans laquelle il est bien difficile de distinguer des lignes de séparation ; la papille terminale impaire est conique et un peu plus grande. Il est à remarquer que les papilles de chaque bord sont exactement contiguës à celles du bord opposé, de telle sorte que la bouche est absolument close. En général, les pièces buccales ont les contours plus ou moins obscurcis par le tégument.

Les plaques brachiales dorsales sont de moyenne grosseur. La première est rectangulaire, plus large que longue, avec le bord distal convexe. La deuxième est aussi large que longue, avec le côté proximal plus étroit, le bord distal large et arrondi et les côtés divergents. Les suivantes sont triangulaires, un peu plus longues que larges, avec le bord distal très convexe : ce bord finit par se décomposer en deux côtés se réunissant en un angle obtus, de sorte que les plaques deviennent losangiques et aussi larges que longues ; elles se séparent à partir de la deuxième.

La première plaque brachiale ventrale est grande, triangulaire, un peu plus longue que large, avec un angle proximal arrondi et des côtés un peu convexes se réunissant par des angles arrondis au bord distal qui est convexe : celui-ci se décompose parfois en deux côtés se réunissant par un angle obtus. La deuxième plaque est encore grande, triangulaire, avec un bord distal convexe ; elle est aussi longue que large. Au delà, les plaques deviennent plus petites, avec un angle proximal très obtus, et un bord distal convexe : elles sont beaucoup plus larges que longues ; elles sont d'abord triangulaires, puis elles deviennent losangiques par la décomposition en deux côtés de leur bord distal. Elles sont séparées à partir de la première.

Les plaques latérales, peu développées, portent trois et parfois quatre piquants très réduits et papilliformes, le dorsal étant généralement un peu écarté des deux ou trois autres.

Il est à remarquer que les bras sont sensiblement plus larges en dedans du disque qu'au delà.

Les pores tentaculaires sont extrêmement réduits. Ceux de la première paire sont petits et séparés du fond des fentes buccales dans lesquelles ils ne s'ouvrent pas : ils sont limités par une bordure dans laquelle il est impossible de distinguer des limites de papilles ou écailles. Les pores de la deuxième et de la troisième paire sont réduits à de petites ouvertures arrondies, de chaque côté de la plaque ventrale correspondante. Au delà, les pores cessent d'exister.

*Rapports et Différences.*—L'*O. Brucei* est voisine de l'*O. abyssorum* Lyman: elle s'en distingue par une disposition différente des plaques dorsales et ventrales du disque qui sont aussi plus petites et plus nombreuses, par les pores tentaculaires encore plus réduits, par les bras extrêmement grêles et par la présence de quelques piquants brachiaux.

*Ophioglypha integra*, nov. sp. (Pl. VIII. fig. 79 et 80.)

18 Mars 1903, 62° 10′ lat. S., 41° 20′ long. W.; profondeur 1775 brasses. Six échantillons.

Le diamètre du disque peut atteindre 17 à 18 millim. dans les plus grands individus; les bras sont cassés à quelques centimètres de leur base; ils sont de grosseur moyenne.

Le disque est pentagonal, assez mince et les bords sont tranchants.

La face dorsale est couverte de plaques extrêmement nombreuses et serrées, petites, laissant une échancrure peu profonde à la base des bras. Il existe une rosette centrale de plaques primaires distinctes, assez petites et arrondies, la centro-dorsale un peu plus grande que les autres; ces plaques sont largement séparées les unes des autres par plusieurs rangées de plaques. Les plaques du disque sont surtout petites dans la région centrale: elles deviennent un peu plus grandes vers la périphérie. On distingue, vers le milieu de chaque espace interradial, une plaque arrondie, un peu plus grosse que les voisines, et, à la périphérie du disque, une autre plaque élargie transversalement. Les boucliers radiaux sont assez grands, triangulaires, une fois et demi plus longs que larges, divergents et largement séparés par plusieurs séries de plaques. Il existe un peigne radial formé de papilles basses, obtuses, carrées et petites. Ces papilles se continuent sur toute la longueur de la fente génitale.

La face ventrale du disque est recouverte de nombreuses petites plaques irrégulièrement polygonales ou arrondies, inégales et non imbriquées. Les plaques génitales sont très allongées et très étroites; les fentes génitales sont aussi très étroites et allongées.

Les boucliers buccaux, de moyennes dimensions, sont un peu plus larges que longs. Ils sont pentagonaux, avec un angle proximal obtus limité par deux côtés droits, deux bords latéraux courts et arrondis se reliant, par des angles également arrondis, au bord distal qui est convexe. Les plaques adorales sont très longues, minces, quatre ou cinq fois plus longues que larges. Les plaques orales sont assez grandes et larges, deux fois plus longues que larges. Les papilles buccales latérales sont au nombre de huit au moins: elles sont basses et obtuses, à peu près carrées, sauf la plus interne qui est allongée et conique; la papille terminale impaire est plus forte et conique.

Les deux ou trois premières plaques brachiales dorsales, comprises dans l'échancrure du disque, sont larges et très courtes, rectangulaires et un peu irrégulières. Les suivantes sont aussi rectangulaires, plus larges que longues, avec le bord distal large et arrondi, le bord proximal plus étroit et les côtés divergents; elles deviennent ensuite aussi longues que larges et enfin plus longues que larges. Elles sont toutes contiguës.

La première plaque brachiale ventrale est assez grande, élargie transversalement, souvent octogonale. Les deux suivantes sont plus grandes, triangulaires, beaucoup plus larges que longues, avec un angle proximal obtus qui est tronqué sur la première plaque, des angles latéraux très pointus et un bord distal large et offrant un petit lobe en son milieu. Les suivantes deviennent beaucoup plus courtes: elles sont toujours triangulaires, avec un angle proximal très obtus et un bord distal fortement convexe.

Elles sont séparées à partir de la deuxième. Les parties latérales des deuxièmes et troisièmes plaques sont séparées du reste par un sillon oblique.

Les plaques latérales portent trois petits piquants courts et papilliformes, rapprochés du bord ventral.

Les pores tentaculaires de la première paire, très allongés et s'ouvrant dans les fentes buccales, portent six écailles sur chaque bord. Les pores de la deuxième paire ont cinq écailles externes et trois ou quatre internes ; ceux de la troisième et de la quatrième paire ont quatre ou cinq écailles externes et trois ou quatre internes, ceux de la cinquième paire ont trois ou quatre écailles proximales seulement, puis le nombre des écailles tombe à deux et finalement à une sur les pores suivants.

*Rapports et Différences.*—L'*O. integra* se rapproche des *O. Loveni* Lyman, *orbiculata* Lyman, *concreta* Koehler, et *mundata* Koehler. Elle diffère de la première par ses boucliers radiaux plus grands, par les plaques brachiales dorsales et ventrales plus longues et par les trois piquants brachiaux très petits ; elle diffère de l'*O. orbiculata* par la présence d'une rosette de plaques primaires et par les boucliers radiaux plus grands ; de l'*O. concreta* par la rosette primaire, par les boucliers radiaux plus grands et par les trois piquants brachiaux rapprochés. Elle s'écarte davantage de l'*O. mundata* par les plaques dorsales du disque très fines, par les boucliers buccaux plus grands et plus larges, par les boucliers radiaux plus grands, par les plaques brachiales dorsales plus grandes, etc.

*Ophioglypha lenticularis*, nov. sp. (Pl. X. fig. 90 et 91.)

9 Avril 1904, 51° 7′ lat. S., 9° 31′ long. W. ; profondeur 2103 brasses. Un échantillon.

Diamètre du disque, 32 millim. Les bras sont cassés près de la base ; les morceaux détachés, qui sont conservés, montrent que leur longueur ne devait guère dépasser 60 millim. ; ils sont plutôt minces et leur face dorsale est bombée mais non carénée. Le disque est épais, convexe sur la face dorsale ainsi que sur la face ventrale, très aminci sur les bords et en forme de lentille.

La face dorsale du disque est recouverte de plaques extrêmement petites, fines et imbriquées, devenant un peu plus grandes vers la périphérie et les boucliers radiaux ; ces plaques rappellent beaucoup plus celles d'une *Amphiura* que d'une *Ophioglypha*. Il existe une rosette centrale de plaques primaires distinctes mais petites : la centro-dorsale est arrondie ; les radiales sont un peu élargies transversalement, séparées les unes des autres, ainsi que de la centro-dorsale, par plusieurs rangées de petites plaques. On distingue en outre, dans les radius, deux plaques un peu plus grandes que les voisines, et, dans les interradius, une première plaque entre le centre et le bord et une autre plaque un peu plus grande placée à la périphérie du disque et légèrement élargie transversalement. Les boucliers radiaux sont très petits, irrégulièrement triangulaires, avec les bords et les angles arrondis et séparés par plusieurs rangées de plaques ; ils sont divergents et à peine plus longs que larges : leur longueur est égale au sixième ou au septième du rayon

du disque. En dehors des boucliers radiaux, on distingue une rangée de papilles radiales, basses et obtuses, qui passent à la face ventrale et s'étendent sur toute la longueur de la fente génitale où elles se montrent très basses et rectangulaires.

La face ventrale est uniformément couverte de plaques petites et inégales, un peu imbriquées. Les plaques génitales sont extrêmement étroites. Les fentes génitales s'étendent sur toute la longueur des bras jusqu'aux boucliers buccaux.

Les boucliers buccaux sont plutôt petits, à peu près aussi longs que larges, pentagonaux, avec un angle proximal assez pointu et allongé, limité par deux côtés un peu concaves, deux bords latéraux droits et assez courts, se reliant au bord distal, qui est arrondi, par des angles également arrondis. Les plaques adorales sont très minces, allongées, rétrécies en dehors par les pores tentaculaires de la première paire, cinq fois plus longues que larges environ. Les plaques orales sont un peu plus larges, mais plus courtes, que les adorales : elles sont deux fois plus longues que larges. Les papilles buccales latérales sont au nombre de huit environ ; elles sont petites, un peu coniques, la plus interne un peu plus longue que les voisines ; la papille terminale impaire est un peu plus forte.

Les plaques brachiales dorsales sont très grandes, rectangulaires, beaucoup plus larges que longues, avec le bord distal très large et convexe, le bord proximal étroit et les côtés divergents. Ce n'est qu'à une grande distance de la base du bras qu'elles deviennent aussi longues que larges et plus loin un peu plus longues que larges.

La première plaque brachiale ventrale est petite, triangulaire ou trapézoïdale, élargie transversalement, avec le bord distal convexe. La deuxième est quadrangulaire, aussi longue que large, avec le bord proximal étroit et légèrement concave, le bord distal plus large et convexe et les côtés divergents, légèrement excavés par les pores tentaculaires de la deuxième paire. Les suivantes deviennent beaucoup plus larges que longues et triangulaires, avec un angle proximal obtus, un bord distal convexe et des angles latéraux pointus qui, de la quatrième à la huitième, sont souvent séparés du reste de la plaque par un sillon oblique. Elles ne se séparent que vers la dixième ou la douzième.

Les plaques latérales sont grandes, avec le bord distal convexe ; elles portent cinq piquants coniques, pointus et allongés, plus longs que la moitié de l'article ; le dernier dorsal est un peu écarté des autres et le premier ventral est un peu plus court. Sur quelques articles, on peut même trouver accidentellement six piquants.

Les pores tentaculaires de la première paire s'ouvrent dans les fentes buccales ; ils sont très allongés et ils offrent une demi-douzaine d'écailles sur chaque bord : les écailles internes sont généralement disposées d'une manière un peu irrégulière. Les pores de la deuxième et de la troisième paire offrent six écailles externes et quatre ou cinq internes. Le nombre des écailles diminue jusqu'à la sixième paire, qui offre trois ou quatre écailles externes ou proximales et deux écailles internes ou distales. Les pores suivants n'ont plus que trois puis deux écailles proximales.

*Rapports et Différences.*—L'*O. lenticularis* est tout à fait remarquable par sa très grande taille : elle rappelle un peu, par son facies, l'*O. figurata* qui est décrite ci-dessous,

mais elle s'en distingue immédiatement par la forme des boucliers buccaux et des plaques brachiales dorsales et ventrales, ainsi que par le nombre des piquants. Parmi les espèces dont les plaques dorsales du disque sont fines et nombreuses et les papilles radiales basses et obtuses, on peut la rapprocher des *O. concreta* Koehler, *Loveni* Lyman, *orbiculata* Lyman, et *tumulosa* Lütken et Mortensen, mais elle se distingue de toutes par le nombre des piquants, la forme des plaques brachiales, la grande taille, etc.

*Ophioglypha figurata*, nov. sp. (Pl. IX. fig. 83 et 84.)

18 Mars 1903, 62° 10′ lat. S., 41° 20′ long. W. ; profondeur 1775 brasses. Un seul échantillon.

Diamètre du disque 24 millim. Un seul bras est conservé sur une longueur de 55 millim. ; les autres sont cassés près de la base : ils sont assez grêles, presque cylindriques, avec la face dorsale très légèrement carénée.

Le disque est pentagonal, aminci sur les bords. La face dorsale est légèrement convexe. Elle offre des écailles excessivement petites et nombreuses, très serrées et imbriquées, rappelant beaucoup celles d'une *Amphiura* comme dans l'espèce précédente. Ces écailles deviennent un peu plus grosses au voisinage des boucliers radiaux. On reconnait cependant une rosette de plaques primaires ; la centro-dorsale est arrondie, les radiales, à peu près de même taille qu'elle, sont largement séparées les unes des autres et de la centro-dorsale par de nombreuses séries de plaques. On remarque en outre, dans chaque espace interradial, une plaque plus grosse que les autres, située vers le milieu de l'espace, et une deuxième, élargie transversalement, placée à la périphérie du disque. Les boucliers radiaux sont petits, triangulaires avec les bords arrondis, un peu plus longs que larges et largement séparés par plusieurs rangs de plaques : leur longueur est égale au cinquième du rayon du disque environ. En dehors des boucliers radiaux, on observe une double rangée irrégulière de très petites plaques, qui ne dépassent pas le bord du disque et représentent des papilles radiales ; elles sont continuées en dessous par une rangée très régulière de fines papilles carrées, s'étendant sur toute la longueur de la fente génitale.

La face ventrale du disque est garnie de plaques petites, imbriquées et assez régulières. Les plaques et les fentes génitales sont étroites et très allongées.

Les boucliers buccaux sont plutôt petits, triangulaires, un peu plus larges que longs, avec un angle proximal assez ouvert et des côtés droits se réunissant par des angles arrondis au bord distal convexe. Les plaques adorales sont allongées, un peu irrégulières dans le contour de leur bord oral, renflées en dedans et se continuant en dehors entre le bouclier buccal et la première plaque brachiale latérale qu'elles séparent l'un de l'autre. Les plaques orales sont triangulaires, allongées, élargies en dedans, rétrécies en dehors et se continuant sous forme d'un lobe étroit qui contourne la partie élargie de la plaque adorale. Les papilles buccales latérales, au nombre de neuf généralement, sont carrées, obtuses et

bien distinctes; la papille interne est un peu allongée. La papille terminale impaire est un peu plus forte.

Les plaques brachiales dorsales sont grandes et très développées, rectangulaires, plus larges que longues, avec un bord proximal étroit, un bord distal très large et convexe et des côtés divergents: elles sont convexes mais non carénées.

Les trois ou quatre premières plaques brachiales ventrales présentent certaines indications de morcellement. La première est grande, triangulaire, avec un angle proximal obtus limité par deux côtés arrondis; le bord distal est convexe ou mieux décomposé en trois petits côtés: de plus, il offre un petit lobe distal rectangulaire, compris entre les deux premières plaques latérales et qui, sur les cinq bras de l'exemplaire que j'ai sous les yeux, est séparé par une ligne transversale du reste de la plaque. Cette disposition est-elle constante? Les deux ou trois plaques suivantes sont grandes, triangulaires, avec le bord distal droit: elles sont plus larges que longues et leur pointes latérales sont séparées du reste par une suture oblique. Les plaques suivantes deviennent beaucoup plus courtes avec un angle proximal très obtus, des angles latéraux arrondis et un bord distal très convexe. Elles se séparent à partir de la deuxième.

Les plaques latérales, très grandes et très larges, rectangulaires, portent trois piquants papilliformes rapprochés du bord ventral; le piquant dorsal est un peu écarté des autres.

Les pores tentaculaires de la première paire, grands et allongés, ont cinq ou six écailles sur chaque bord et les écailles externes se continuent avec les papilles buccales; ils s'ouvrent dans les fentes buccales. Les deuxièmes, plus petits, ont cinq ou six écailles en dehors, et quatre en dedans; ceux de la troisième paire offrent quatre ou cinq écailles externes et deux ou trois internes. Les quatrièmes pores n'ont plus que trois ou quatre écailles externes et proximales, et deux ou trois sur le bord distal. Les pores de la cinquième paire ne présentent plus que trois écailles proximales, puis le nombre des écailles tombe à deux et finalement à un.

*Rapports et Différences.*—L'*O. figurata* est facile à distinguer des autres espèces par les plaques dorsales du disque très fines et imbriquées, par l'absence de papilles radiales sur la face dorsale du disque de chaque côté de la base des bras, et par les trois piquants brachiaux très petits. J'ai indiqué, en décrivant l'*O. lenticularis*, les caractères qui la distinguent de cette dernière espèce.

*Ophioglypha ossiculata*, nov. sp. (Pl. IX. fig. 85 à 87.)

18 Mars 1904, 71° 22′ S. lat., 16° 34′ long. W.; profondeur 1410 brasses. Sept échantillons.

Le diamètre du disque est de 19 millim. dans le plus grand exemplaire et de 9 dans le plus petit; les bras sont cassés à un ou deux centim. du disque.

Le disque est pentagonal, pas très épais, avec les bords amincis. La face dorsale offre, à la base des bras, des échancrures plus ou moins marquées qui reçoivent les deux ou trois premières plaques brachiales dorsales. Il est couvert de plaques inégales, très

épaisses, s'élevant à peu près toutes en proéminences obtuses : ces plaques, tout en restant bien écartées et distinctes les unes des autres, sont réunies par leurs bases dans un tissu calcifié commun. On distingue une plaque centro-dorsale arrondie, assez grande, offrant vers son bord un épaississement circulaire large et saillant, et cinq radiales primaires assez grandes, élargies transversalement et présentant un épaississement en forme de demi-cercle qui occupe une bonne partie de leur surface ; elles sont séparées de la plaque centro-dorsale par deux ou trois rangées de plaques dont les internes, plus grandes, forment un pentagone régulier assez constant. Parmi les autres plaques, on reconnait une ou deux radiales plus grandes entre les boucliers radiaux, et, dans les espaces interradiaux, une plaque voisine de la périphérie du disque ; ces différentes plaques offrent toutes des épaississements en forme de demi-cercle sur leur bord externe. Les autres plaques, plus petites, qui les séparent, sont simplement épaissies et renflées. Les boucliers radiaux sont petits, de forme irrégulière et plus ou moins triangulaires, aussi larges que longs, divergents et très largement séparés en dedans par trois plaques dont la moyenne est généralement plus grande que les autres et cordiforme. Ces boucliers offrent sur leur bord distal deux épaississements : l'un externe, conique, et l'autre interne, plus large, aminci et lamelleux. Une rangée de papilles radiales, basses et obtuses, se montre en dehors ; ces papilles se continuent sur toute la longueur des fentes génitales où elles deviennent très petites et aplaties.

La face ventrale du disque est recouverte de plaques inégales, irrégulièrement polygonales et épaisses : les rangées externes offrent une proéminence conique qui s'efface à mesure qu'on s'avance vers les boucliers buccaux. Les fentes génitales, très minces, s'étendent jusqu'aux boucliers buccaux ; les plaques génitales sont très étroites.

Les boucliers buccaux, de grosseur moyenne, sont triangulaires avec les angles et les bords arrondis, sauf l'angle proximal qui est obtus ; elles sont un peu plus larges que longues. Les plaques adorales ne sont pas très grosses : elles sont deux fois plus longues que larges et elles se rétrécissent beaucoup en dehors. Les plaques orales sont un peu plus larges, mais plus courtes que ces dernières Les papilles buccales latérales sont au nombre de six : elles sont bien distinctes, obtuses et carrées, l'interne un peu allongée et conique ; la papille terminale impaire est un peu plus grande.

Les deux ou trois premières plaques brachiales dorsales, reçues dans l'échancrure du disque, sont rectangulaires, très courtes et larges. Elles s'allongent ensuite et offrent un bord distal très large et convexe, un bord proximal étroit et des côtés divergents ; elles deviennent aussi larges que longues, puis un peu plus longues que larges. Elles sont toutes contiguës.

La première plaque brachiale ventrale est élargie transversalement, avec le bord proximal large et convexe. La suivante est trapézoïdale avec le bord proximal étroit, le bord distal très large et les côtés divergents, excavés par les pores tentaculaires. Les plaques suivantes deviennent triangulaires, beaucoup plus larges que longues, avec un angle proximal obtus et un côté distal très convexe. Les deuxièmes, troisièmes et quatrièmes plaques montrent généralement une ligne oblique qui sépare du reste tout

l'angle externe de la plaque, comme chez les l'*O. lenticularis*, *figurata*, etc. Les plaques ventrales se séparent à partir de la quatrième.

Les plaques latérales portent, sur toute la longueur de leur bord distal, une rangée de petits piquants papilliformes, au nombre de huit à neuf.

Les pores tentaculaires de la première paire, très allongés, s'ouvrent dans les fentes buccales ; ils ont six écailles externes et cinq internes ; les deuxièmes et troisièmes en ont à peu près autant. Ceux de la quatrième paire ont quatre ou cinq écailles externes et proximales et trois ou quatre distales ; ceux de la cinquième paire ont trois ou quatre écailles proximales et deux ou trois distales. Ensuite les pores n'offrent plus que trois, puis deux écailles proximales.

*Rapports et Différences.*—L'*O. ossiculata* appartient aux *Ophioglypha* à papilles radiales basses et obtuses et à plaques brachiales ventrales beaucoup plus larges que longues. Elle se reconnait facilement à son disque couvert de plaques saillantes et épaissies et au nombre des piquants brachiaux. Je ne connais pas d'espèce dont on puisse la rapprocher.

*Ophioglypha mimaria*, nov. sp. (Pl. IX. fig. 88 et 89).

18 Mars 1904, 71° 22′ lat. S., 16° 34′ long. W. ; profondeur 1410 brasses Quelques échantillons.

Dans les plus grands individus, le diamètre du disque est de 11 millim. et les bras ont une longueur de 30 millim. environ ; mais la plupart des exemplaires sont plus petits et leur disque mesure 5 à 8 millim. de diamètre.

L'*O. mimaria* présente une grande ressemblance avec l'*O. ossiculata* que je viens de décrire, par la forme des plaques brachiales dorsales et ventrales, ainsi que par la disposition des pièces buccales et des plaques ventrales du disque : elle n'en diffère guère que par les plaques dorsales du disque, qui sont aplaties et n'offrent pas la moindre trace d'épaississements ou de proéminences : en raison de cette différence importante, et qui est constante, je crois devoir l'en séparer.

Le disque est pentagonal. Toutes les plaques de la face dorsale sont aplaties et minces, irrégulièrement arrondies et inégales : on distingue une rosette de plaques primaires, grandes et subégales, la centro-dorsale arrondie et les radiales élargies transversalement ; elles sont séparées les unes des autres par deux ou trois rangs de petites plaques. On distingue, dans les espaces radiaux, une grande plaque triangulaire séparant les boucliers radiaux sur leur moitié interne et suivie d'une autre plus petite ; dans les espaces interradiaux, se montrent deux plaques successives, dont la dernière, située au bord du disque, est élargie transversalement. Les plaques placées entre les précédentes sont petites, inégales et arrondies. Les boucliers radiaux, de moyenne grosseur, sont triangulaires avec les angles et les bords arrondis ; ils ne sont pas beaucoup plus longs que larges et leur longueur est plus petite que le tiers du rayon du disque ; ils sont divergents et rapprochés, chez les grands exemplaires, par leur angle

externe, mais sans se toucher. Les papilles génitales s'arrêtent aux bords latéraux des bras et l'on n'en aperçoit plus que deux ou trois sur la face dorsale du disque.

La face ventrale est couverte de plaques plutôt petites, polygonales ou arrondies, et tout à fait planes. Les plaques génitales sont étroites. Les fentes génitales sont allongées et bordées d'une rangée de papilles très basses et obtuses.

Les boucliers buccaux sont de taille moyenne, triangulaires, aussi longs que larges ou un peu plus larges que longs. Les autres pièces buccales sont disposées comme chez l'*O. ossiculata*.

Les plaques brachiales dorsales et ventrales offrent également les mêmes dispositions que dans cette dernière espèce et il en est de même pour les pores tentaculaires. Les piquants brachiaux sont au nombre de sept à huit.

En somme, il n'y a de différences importantes, entre l'*O. ossiculata* et l'*O. mimaria*, que dans la forme et la disposition des plaques dorsales du disque. Or j'ai soigneusement comparé tous les exemplaires des deux espèces que j'avais à ma disposition et je n'ai pas pu constater de passage d'une forme à l'autre. Les petits exemplaires d'*O. ossiculata* dont le disque n'a que 10 ou 11 millim. de diamètre, comparés aux plus grands individus d'*O. mimaria*, chez lesquels le diamètre du disque atteint à peu près les mêmes dimensions, accusent toujours les mêmes différences et ces derniers n'offrent pas la moindre tendance à épaissir les plaques dorsales du disque. En revanche, les plus petits individus d'*O. ossiculata*, chez lesquels le diamètre du disque ne dépasse pas 6 à 8 millim., présentent déjà des épaississements très marqués. Ceux-ci ne sont donc pas l'effet de l'âge ; ils manquent toujours chez l'*O. mimaria* et existent à tous les stades chez l'*O. ossiculata*.

Faut-il voir dans l'*O. mimaria* une variété à plaques lisses et minces de l'*O. ossiculata* ou en faire une espèce distincte ? A première vue, la différence est si saillante qu'il me parait préférable de distinguer ces deux formes spécifiquement et je pense que l'on adoptera mon opinion si l'on compare les dessins que je donne, Pl. IX. fig. 87 et 88, qui représentent une *O. ossiculata* et une *O. mimaria* à peu près de même taille l'une et l'autre.

La question est d'autant plus délicate que les deux formes proviennent de la même station et se trouvaient même réunies dans le même bocal : je n'ai cependant pas eu la moindre hésitation, en faisant le triage, pour les séparer l'une de l'autre.

*Ophioglypha anceps*, nov. sp. (Pl. X. fig. 92 et 93.)

18 Mars 1904, 71° 22′ lat. S., 16° 34′ long. W. ; profondeur 1410 brasses. Une quinzaine d'échantillons.

Dans les plus grands individus, le diamètre du disque atteint 15 millim., et dans les plus petits, il est de 5 ou 6 millim. seulement. Les bras sont presque tous cassés près de la base et doivent être fort courts : dans un exemplaire dont le diamètre du disque est de 14 millim., ils n'ont guère que 23 millim. de longueur : ils sont assez épais et s'amincissent rapidement.

Le disque est arrondi ou pentagonal. La face dorsale est garnie de plaques inégales, épaisses et arrondies, assez grosses et pas très nombreuses. Il existe une rosette de six plaques primaires, grandes et arrondies, égales et séparées par un rang de petites plaques. Dans les espaces radiaux, une grosse plaque sépare les moitiés proximales des boucliers radiaux et elle est suivie d'une ou deux plaques plus petites occupant l'espace triangulaire qui sépare les régions distales de ces boucliers. Dans les espaces interradiaux, on distingue deux grosses plaques successives, arrondies, dont la dernière occupe la périphérie du disque : celle-ci est parfois élargie transversalement. Le reste du disque est occupé par de très petites plaques. Les boucliers radiaux sont irrégulièrement triangulaires, avec les bords et les angles arrondis, aussi larges que longs ou un peu plus longs que larges ; leur longueur est égale au tiers du rayon du disque ; ils sont un peu divergents et séparés sur toute leur longueur par la rangée de plaques signalées plus haut.

Toutes les plaques de la face dorsale du disque sont épaisses, saillantes et séparées par des sillons très accentués et profonds ; de plus, elles présentent des épaississements, qui, sur les grosses plaques, forment généralement un demi-cercle sur leur bord périphérique ou constituent sur chacune d'elles deux éminences distinctes ; la plaque centro-dorsale offre un épaississement circulaire constitué par cinq proéminences confluentes. Quant aux petites plaques intercalaires, elles sont relevées en cônes : enfin les boucliers radiaux sont munis sur leur bord externe de deux proéminences arrondies bien marquées.

De chaque côté de la base des bras et en dehors des boucliers radiaux, on observe une bordure de deux ou trois rangs de petites papilles élargies transversalement, courtes et assez épaisses, qui se continuent quelque peu sur la face ventrale en pénétrant entre la plaque génitale et la troisième plaque brachiale latérale ; ces papilles disparaissent bien avant d'avoir atteint les fentes génitales. Celles-ci sont très petites, très étroites et courtes et elles sont exactement limitées aux côtés de la première plaque brachiale latérale.

La face ventrale du disque est peu développée : elle n'offre, en dehors du bouclier buccal, qu'une seule plaque, très grande, ayant la même largeur que ce bouclier mais plus courte, et, au bord même du disque, trois petites plaques, une médiane et deux latérales : celles-ci sont munies d'une ou de deux éminences coniques analogues à celles qu'on observe sur les plaques dorsales du disque. La grande plaque centrale est aussi parfois pourvue de proéminences analogues. Les plaques génitales sont allongées et assez étroites.

Les boucliers buccaux sont grands, plus longs que larges, avec un angle proximal aigu, limité par deux bords droits, deux bords latéraux droits et parallèles et un côté distal droit ; les deux bords de l'angle proximal et les deux bords latéraux ne sont pas toujours bien distincts l'un de l'autre. Les plaques adorales sont plutôt petites, assez étroites, avec les bords parallèles, deux fois et demi plus longues que larges. Les plaques orales sont un peu plus épaisses que les adorales et plus courtes. Les papilles buccales latérales forment une bordure extrêmement mince : elles sont au nombre de

cinq environ, très basses et la papille impaire terminale est à peine plus grande que les voisines.

Les bras sont moniliformes par suite du renflement considérable du bord distal des plaques latérales. Les plaques brachiales dorsales sont de moyenne grosseur. Les deux ou trois premières restent courtes, rectangulaires, plus larges que longues, puis elles deviennent plus longues que larges, avec un côté distal large et convexe, deux bords latéraux divergents et un bord proximal qui devient rapidement plus court et finit par disparaître : les plaques deviennent alors triangulaires et elles s'écartent légèrement l'une de l'autre. Elles offrent toutes une petite proéminence conique rapprochée de leur bord distal.

La première plaque brachiale ventrale est triangulaire, avec les côtés droits et un angle proximal arrondi et tronqué : elle est plus longue que large ; parfois l'angle proximal est tellement tronqué que la plaque devient rectangulaire. La seconde est triangulaire avec les côtés légèrement arrondis et l'angle proximal aigu ; elle est un peu plus longue que large. Les suivantes sont encore triangulaires, mais avec l'angle proximal obtus : elles deviennent beaucoup plus larges que longues, avec un côté distal convexe et des bords latéraux droits ou légèrement excavés. Elles sont séparées dès la seconde.

Les plaques brachiales latérales portent, sur leur bord distal fortement épaissi et saillant, deux ou trois piquants très petits et papilliformes.

Il n'y a guère qu'une paire unique de pores tentaculaires, qui sont limités aux côtés de la plaque orale et qui ne s'ouvrent pas dans les fentes buccales. Ces pores sont petits et étroits : on observe deux ou trois écailles distinctes sur leur bord interradial et parfois le bord radial porte une ou deux écailles plus petites ou constitue un simple rebord sans écailles distinctes. Au delà, les pores tentaculaires font à peu près complètement défaut : sur les grands exemplaires, on distingue cependant un très petit pore sans écailles distinctes, de chaque côté de la deuxième plaque brachiale ventrale et vers le milieu de son bord latéral.

*Rapports et Différences.*—L'*O. anceps* rappelle absolument, par son facies, une *Ophiomusium*, mais c'est bien une *Ophioglypha*, qui n'a, à la vérité, qu'une seule paire de pores tentaculaires normalement constitués. Elle a quelque analogie avec l'*O. frigida* Koehler, que la *Belgica* a recueillie dans l'Océan Antarctique et qui a, comme l'*O. anceps*, les plaques dorsales du disque et des bras épaissies et une seule paire de pores tentaculaires, mais elle s'en distingue par une forme différente des boucliers buccaux et des pièces buccales, ainsi que par les plaques ventrales du disque et par les bras moniliformes.

Les petits exemplaires rappellent beaucoup l'*O. Martensi* Studer, qui est aussi une forme antarctique, mais ils ne peuvent être rapportés à cette espèce, car ils possèdent déjà, et bien marquées, les proéminences caractéristiques des plaques dorsales du disque et des bras que Studer ne mentionne pas. Ces petits individus présentent une

rangée assez régulière de papilles radiales, à laquelle, toutefois, on voit déjà s'ajouter un ou deux rangs de petites écailles dont le nombre s'accroitra avec l'âge pour donner la disposition que l'on observe chez l'adulte.

*Ophioglypha scissa*, nov. sp. (Pl. XI. fig. 98 et 99; Pl. XII. fig. 112.)

18 Mars 1904, 71° 22′ lat. S., 16° 34′ long. W.; profondeur 1410 brasses. Plusieurs échantillons.

Le disque est aplati, assez mince, et son diamètre mesure 10 millim.; les bras sont grêles et doivent atteindre 25 millim. de longueur environ: leur longueur ne peut être indiquée exactement, car ils sont tous cassés à une certaine distance de la base.

Le disque est subpentagonal ou pentagonal. La face dorsale est couverte de plaques très inégales, parmi lesquelles on distingue six grandes plaques primaires arrondies, à peu près de mêmes dimensions et séparées les unes des autres par une rangée de petites plaques irrégulières. Les espaces interradiaux présentent généralement deux plaques successives, un peu plus grandes que les autres: la dernière, élargie transversalement, occupe le bord du disque. Tout le reste de la face dorsale est couvert de petites plaques polygonales-arrondies. Les boucliers radiaux sont triangulaires avec les angles arrondis, à peine plus longs que larges; ils sont divergents et ordinairement écartés en dehors: ils sont parfois très rapprochés, mais sans se toucher cependant. Ils offrent souvent, en leur milieu, une scissure plus ou moins parallèle au bord du disque. Il n'y a pas trace de peignes radiaux. Toutes les grandes plaques de la face dorsale du disque sont finement granuleuses.

La face ventrale est recouverte par plusieurs plaques polygonales sur une espace qui est au moins égal en longueur à la longueur du bouclier buccal et souvent la dépasse. On trouve fréquemment, au milieu de cette face, une plaque un peu plus grande autour de laquelle sont disposées les autres. Les plaques génitales sont allongées. Les fentes génitales sont très petites et souvent invisibles: elles sont limitées aux côtés de la première plaque brachiale latérale et n'atteignent pas le bord du disque; leurs bords n'offrent pas la moindre trace de papilles.

Les boucliers buccaux, de moyenne grosseur, sont piriformes ou triangulaires, à peu près aussi longs que larges et souvent un peu plus longs que larges: ils offrent un angle proximal aigu, limité par deux côtés droits ou un peu concaves et un bord distal fortement convexe. Le plus souvent, mais non constamment, ils sont divisés sur la totalité ou sur une partie de leur longueur, par un sillon interradiaire qui parfois dépasse le bouclier et divise une ou deux des plaques voisines. Les plaques adorales sont allongées, avec les bords parallèles, deux fois et demi plus longues que larges. Les plaques orales sont plus épaisses. Les papilles buccales latérales sont basses, rectangulaires, très courtes, à contours peu distincts: elles sont au nombre de quatre ou cinq; la papille terminale impaire est plus grande et conique.

La première plaque brachiale dorsale est rectangulaire, plus large que longue, avec

le bord distal arrondi. Les suivantes sont triangulaires, aussi larges que longues, avec le bord distal convexe ; elles sont séparées à partir de la seconde.

La première plaque brachiale ventrale est assez grande, triangulaire ou piriforme, un peu plus longue que large, avec le bord distal très convexe. Les suivantes sont petites, triangulaires, plus larges que longues, avec le bord distal convexe et l'angle distal obtus ; elles sont très largement séparées.

Les plaques latérales portent d'abord quatre puis trois piquants très petits et papilliformes, le dorsal parfois un peu séparé des autres.

Les bras sont assez fortement élargis en dedans du disque.

Les pores tentaculaires sont très peu développés. Ceux de la première paire ne s'ouvrent généralement pas dans les fentes buccales : ils présentent quatre ou cinq écailles externes et trois ou quatre internes. Les pores de la deuxième paire sont beaucoup plus petits, avec deux ou trois écailles externes et une ou deux internes ; ceux de la troisième paire n'ont plus que deux ou trois écailles proximales ; au delà, les pores ne sont plus distincts.

De même qu'on l'a déjà observé chez l'*O. inornata*, avec laquelle l'*O. scissa* offre des analogies, les sillons qui divisent les boucliers buccaux offrent des variations : chez certains individus ils manquent totalement, tandis que chez d'autres, un ou plusieurs boucliers sont divisés en deux par un sillon qui peut même se continuer sur les plaques ventrales voisines ; enfin certains boucliers sont incomplètement divisés, le sillon n'intéressant que leur moitié distale. Des variations analogues s'observent sur les boucliers radiaux. Les cinq plaques radiales primaires peuvent aussi offrir des sillons. Quant aux plaques brachiales dorsales, elles sont toujours indivises chez l'*O. scissa*.

*Rapports et Différences.*—L'*O. scissa* se rapproche de l'*O. inornata* Lyman, mais elle s'en distingue par l'absence de peignes radiaux et par les boucliers buccaux beaucoup plus petits. Elle offre aussi quelque analogie avec l'*O. Brucei* que j'ai décrite plus haut, mais elle s'en éloigne par la disposition des plaques dorsales du disque, par la forme des boucliers buccaux et par les divisions qui affectent certaines plaques.

### *Ophioglypha partita*, nov. sp. (Pl. X. fig. 94 et 95.)

18 Mars 1903, 62° 10′ lat. S., 41° 20′ long. W. ; profondeur 1775 brasses. Un seul échantillon qui n'est malheureusement pas en très bon état ; les bras sont cassés très près de leur base.

Le disque a un diamètre de 10 millim. ; il est pentagonal et assez épais. La face dorsale est plate ; elle est couverte de plaques très inégales, arrondies, très fortement granuleuses, assez saillantes, mais réunies à leur base dans un tissu calcaire compact. On distingue une rosette de six grandes plaques primaires arrondies, à peu près de mêmes dimensions et séparées par trois ou quatre rangs de plaques inégales. Dans

les espaces radiaux, trois ou quatre rangs de plaques inégales et arrondies séparent les boucliers radiaux : une ou deux d'entre elles sont plus grandes que les autres. Les espaces interradiaux ne présentent que de petites plaques subégales. Les boucliers radiaux sont grands et allongés, triangulaires, presque deux fois plus longs que larges, légèrement divergents et largement séparés. De chaque côté de la base des bras, on distingue quelques granules mal définis qui ne constituent pas un peigne radial et qui ne se continuent pas sur le bord des fentes génitales.

La face ventrale du disque est recouverte de plaques petites, inégales et arrondies. Une plaque assez grande s'étend le long des bras, mais les fentes génitales sont exactement limitées à un interstice très étroit et très court, entre la première plaque latérale ventrale et une petite plaque placée en face d'elle. Les boucliers buccaux sont tous mal formés, inégaux et leurs contours sont irréguliers, sans doute par suite de la présence du sillon qui les traverse en direction interradiaire : leur forme parait être triangulaire, avec un angle proximal assez obtus et un bord distal convexe ; ils sont plus larges que longs. Les plaques adorales sont assez épaisses et courtes, deux fois plus longues que larges : dans l'un des interradius, elles sont en partie avortées. Les plaques orales sont grandes, hautes et larges. Les papilles buccales latérales, au nombre de six, sont obtuses et mal séparées les unes des autres ; la papille terminale impaire est plus grosse que les voisines.

Les plaques brachiales dorsales sont grandes ; les deux ou trois premières sont rectangulaires, plus larges que longues : elles deviennent ensuite triangulaires, avec un angle proximal arrondi et un bord distal convexe ; elles sont aussi longues que larges ou un peu plus longues que larges : elles se séparent au delà de la cinquième. Toutes ces plaques offrent un sillon médian très large et assez profond qui les divise en deux moitiés égales.

La première plaque brachiale ventrale est grande, triangulaire, avec l'angle proximal allongé, le bord distal convexe et les côtés un peu excavés. La deuxième est pentagonale, avec un angle proximal aigu limité par deux petits côtés, deux bords latéraux divergents et excavés par les pores tentaculaires, et un côté distal fortement convexe ; elle est un peu plus longue que large. La troisième est encore pentagonale, mais plus courte que la deuxième et plus large que longue, avec un angle proximal obtus et un bord distal convexe. Les suivantes deviennent triangulaires avec l'angle proximal très obtus et le bord distal fortement convexe. Elles sont séparées dès la première.

Les plaques brachiales latérales, assez saillantes, portent sur leur bord distal droit trois piquants également espacés, courts et pointus.

Les pores tentaculaires de la première paire, gros, larges et courts, offrent quatre écailles externes et trois internes ; ils ne s'ouvrent pas dans les fentes buccales ; ceux de la deuxième paire ont trois écailles externes et deux internes ; les suivantes ont deux écailles externes et proximales et une seule écaille distale. Les pores de la quatrième paire n'ont plus qu'une écaille distale, et, au delà, on ne distingue plus de pores.

*Rapports et Différences.* — L'*O. partita* est remarquable par la division des boucliers buccaux et des plaques brachiales dorsales : elle partage cette particularité avec l'*O. inornata* Lyman (*O. divisa* Lütken et Mortensen), mais elle est bien différente de cette espèce. Elle se distingue de l'*O. scissa* que j'ai décrite ci-dessus par ses plaques brachiales dorsales plus grandes et divisées, ainsi que par les boucliers radiaux plus longs.

*Ophioglypha inops*, nov. sp. (Pl. XI. fig. 96 et 97.)

18 Mars 1904, lat. 71° 22′ S., long. 16° 34′ W. ; profondeur 1410 brasses. Un échantillon.

Diamètre du disque, 12 millim. Les bras sont conservés sur une longueur de 27 millim. et ne devaient guère être plus grands.

Le disque est épais ; la face dorsale est un peu convexe, les bords sont hauts et arrondis. Les bras sont relativement minces.

La face dorsale du disque est couverte de plaques assez grandes, inégales et arrondies, les plus petites légèrement imbriquées. On distingue une rosette de plaques primaires plus grandes : la centro-dorsale arrondie, les radiales un peu élargies transversalement, séparées entre elles et de la centro-dorsale par deux rangées de petites plaques. Le reste du disque est occupé par des plaques plus petites, parmi lesquelles on ne reconnait qu'une seule plaque plus grande, entre les deux boucliers radiaux de chaque paire. Ceux-ci sont assez petits, triangulaires, allongés, élargis en dehors, très rétrécis en dedans, presque deux fois plus longs que larges ; ils sont contigus en dehors et séparés en dedans par la grande plaque radiale citée plus haut et à laquelle s'ajoute ordinairement une plaque plus petite située en dehors ; leur longueur est un peu plus grande que le tiers du rayon du disque. Une rangée de papilles radiales fines, pointues et très rapprochées, forme un peigne très apparent ; ces papilles se continuent le long de la fente génitale où elles se montrent petites, basses et peu serrées.

La face ventrale du disque offre, en dehors des petits boucliers buccaux, des plaques arrondies, subégales et un peu imbriquées. Les plaques génitales sont étroites et peu apparentes ; les fentes génitales s'étendent sur toute leur longueur jusqu'au bouclier buccal.

Les boucliers buccaux sont petits, triangulaires, un peu plus longs que larges, avec un angle proximal allongé et un bord distal un peu arrondi. Les plaques adorales sont très minces, allongées, rétrécies en leur milieu par les pores tentaculaires de la première paire et quatre ou cinq fois plus longues que larges. Les plaques orales sont assez grandes, épaisses et fortes, deux fois plus longues que larges. Les papilles buccales latérales sont au nombre de cinq ; les externes sont obtuses et les deux internes sont coniques : toutes sont petites, sauf l'interne qui est un peu plus grosse ; la papille terminale impaire est un plus grosse que les voisines.

Les plaques brachiales dorsales sont petites. Elles sont d'abord rectangulaires,

plus larges que longues et les deux premières, comprises entre les boucliers radiaux, sont très réduites. Elles s'allongent ensuite et deviennent triangulaires, à peu près aussi longues que larges ; elles se séparent l'une de l'autre vers la sixième ou la septième.

La première plaque ventrale est grande, triangulaire, avec les angles et les bords arrondis ; elle est un peu plus large que longue. La deuxième est rectangulaire, plus longue que large, avec les côtés excavés par les pores tentaculaires et le bord distal large et très légèrement arrondi. Les quatre ou cinq suivantes sont rectangulaires, un peu plus longues que larges, puis le bord proximal se rétrécit et disparait : les plaques présentent alors un angle proximal aigu et deviennent ainsi pentagonales ; en même temps elles s'allongent beaucoup. Elles se séparent vers la dixième ou la douzième.

Les plaques latérales sont proéminentes et elles portent sur leur bord distal convexe, une rangée de six piquants égaux et régulièrement disposés le long de ce bord ; ces piquants sont coniques, assez forts et un peu plus petits que la moitié de l'article. Leur nombre diminue à une certaine distance du disque.

Les pores tentaculaires sont gros, élargis, mais courts. Ceux de la première paire ont cinq écailles externes et quatre internes ; malgré leur taille, ils ne s'ouvrent pas dans les fentes buccales chez l'unique exemplaire que j'ai pu étudier. Les pores des deuxièmes, troisièmes et quatrièmes paires ont quatre ou cinq écailles externes et trois ou quatre internes. Les suivants ont trois écailles externes et proximales et deux écailles distales ; finalement, ils n'offrent plus que deux écailles distales et une seule plus loin.

*Rapports et Différences.*—L'*O. inops* offre des affinités avec les *O. Lacazei* et *sculptilis* décrites par LYMAN, qui ont les plaques brachiales ventrales carrées et contiguës, les plaques dorsales du disque plus ou moins nombreuses et les pores tentaculaires gros et courts. Elle s'en distingue par la disposition des plaques dorsales du disque et l'absence de plaques plus grandes dans les espaces interradiaux au bord du disque, par la forme des plaques brachiales dorsales, par le nombre des piquants, etc.

*Ophioglypha bullata*, Wyville Thomson.

Voir pour la bibliographie :

KOEHLER, *Expéditions du "Travailleur" et du "Talisman" : Ophiures*, p. 259.

29 Avril 1904, 39° 48′ lat. S., 2° 33′ long. E. ; profondeur 2645 brasses. Quelques échantillons.

Bien que ces exemplaires ne soient pas rigoureusement conformes à la description de LYMAN, je n'hésite pas à les rapporter à l'*O. bullata*. Il y a principalement des variations assez notables dans les dimensions relatives des plaques dorsales du disque. Dans certains individus, les six plaques primaires sont très grosses et même contiguës, tandis que dans d'autres, elles sont plus petites et séparées par deux ou trois rangs de

petites plaques. La plaque interradiale qui atteint le bord du disque sur la face dorsale, et qui, sur le dessin de LYMAN, occupe tout l'espace interradial, est toujours plus petite et elle est accompagnée d'une ou deux rangées de petites plaques, dans les exemplaires où les plaques primaires sont grandes; dans les échantillons où ces plaques primaires sont petites, la plaque marginale interradiale est elle-même plus petite et elle est accompagnée de plaques plus nombreuses. Les boucliers radiaux de chaque paire sont séparés, tantôt par une seule rangée, tantôt par deux ou trois rangées de plaques : ils sont parfois rapprochés par leur angle externe et légèrement divergents.

En somme, l'espèce est assez variable.

L'*O. bullata* a surtout été rencontrée dans l'Atlantique Nord, mais elle se trouve aussi dans l'hémisphère austral: le *Challenger* l'a trouvée par 35° lat. S. et 20° long. W. : cette station est assez voisine de celle où la *Scotia* l'a draguée.

### *Ophiocten Ludwigi*, nov. sp. (Pl. XI. fig. 100 et 101.)

18 Mars 1903, 62° 10′ lat. S., 41° 20′ long. W.; profondeur 1775 brasses. Trois échantillons dans l'alcool, mais en mauvais état.

18 Mars 1904, 71° 22′ lat. S., 16° 34′ long. W.; profondeur 1410 brasses. Une dizaine d'exemplaires desséchés mais bien conservés.

Le disque est grand et son diamètre atteint 12 millim. dans les plus grands échantillons; il est mince et flexible. Les bras sont tous cassés à une certaine distance de leur base.

Le disque est échancré à la base des bras. Sa face dorsale est couverte de plaques inégales, la plupart de petite taille; quelques-unes sont plus grandes mais ne deviennent jamais bien grosses et les petites plaques ne forment pas de cercle autour d'elles. On distingue plus ou moins nettement une rosette de plaques primaires arrondies, petites, largement séparées, puis, dans les espaces radiaux et interradiaux, quelques plaques arrondies au nombre de quatre ou cinq dans chaque espace. Le reste du disque est couvert par des plaques très petites et fines, irrégulièrement polygonales, devenant un peu plus grandes vers le bord du disque et entre les boucliers radiaux. Ceux-ci sont petits et irrégulièrement triangulaires, aussi longs que larges ou un peu plus longs que larges, un peu divergents et largement séparés par cinq ou six séries de plaques. On distingue, en dehors de chaque bouclier, un peigne de petites papilles coniques et pointues, mais qui ne se continuent pas d'un côté à l'autre du bras.

La face ventrale est couverte de plaques très petites et imbriquées Les fentes génitales sont étroites.

Les boucliers buccaux sont assez grands, pentagonaux, beaucoup plus larges que longs, avec un angle proximal assez ouvert limité par deux côtés un peu excavés, et un bord

distal convexe. Les plaques adorales sont grandes, allongées, amincies surtout en dehors et envoyant un lobe étroit qui sépare le bouclier buccal de la première plaque brachiale latérale ; elles sont cinq ou six fois plus longues que larges. Les plaques orales sont assez grandes et larges, deux fois et demie plus longues que larges. Les papilles buccales latérales sont généralement au nombre de cinq : les deux externes sont très basses et rectangulaires, souvent confondues ensemble, les autres deviennent progressivement plus coniques et pointues ; la papille terminale impaire est grande et conique.

Les plaques brachiales dorsales sont grandes et quadrangulaires, sauf la première ou les deux premières qui sont comprises dans l'échancrure du disque et très petites. Elles sont beaucoup plus larges que longues, avec le bord distal convexe et les côtés divergents. A une certaine distance du disque, ces plaques deviennent aussi larges que longues et finalement plus longues que larges. Elles offrent, sur toute la longueur de leur bord distal, une rangée de papilles serrées, excessivement fines et ressemblant à des soies ; ces papilles se continuent jusque vers la douzième plaque et même au delà, puis elles deviennent moins nombreuses et disparaissent finalement. Peut-être sur des échantillons très bien conservés, les reconnaitrait-on plus loin encore. Sur les échantillons du 18 Mars 1903, qui sont en moins bon état que les autres, ces papilles manquent très fréquemment et elles ont dû tomber accidentellement.

La première plaque brachiale ventrale est grande, trapézoïdale, avec un bord proximal étroit et droit, des côtés divergents et un bord distal large et un peu convexe. La deuxième est assez grande, avec un angle proximal aigu et le bord distal très convexe ; puis l'angle proximal s'ouvre de plus en plus, au point de disparaître presque complètement : en même temps, les plaques deviennent beaucoup plus petites. Elles sont séparées dès la première.

Les plaques latérales portent trois piquants minces, pointus, et allongés ; leur longueur augmente du premier ventral, qui est presque égal à l'article, jusqu'au dernier dorsal, qui, sur les premiers articles, arrive presque à égaler deux articles et devient ensuite plus court.

Les pores tentaculaires buccaux portent trois ou quatre écailles petites et obtuses. Les pores de la deuxième paire ont une écaille proximale et une distale, puis l'écaille distale disparait et il ne reste plus que l'écaille proximale qui est petite et conique.

*Rapports et Différences.*—L'*O. Ludwigi* appartient à la section des *Ophiocten* dont les plaques primaires sont peu apparentes et dont les grandes plaques du disque sont peu développées. Elle se rapproche surtout des *O. hastatum* Lyman, et *pacificum* Lyman, qu'elle représente évidemment dans les mers australes. Elle se distingue facilement de ces deux espèces par la rangée de très fines papilles qu'offre le bord distal des plaques brachiales dorsales et qui se continuent sur un certain nombre d'articles.

*Ophiernus quadrispinus*, nov. sp. (Pl. XI. fig. 102 et 103.)

18 Mars 1903, 62° 10′ lat. S., 41° 20′ long. W. ; profondeur 1775 brasses. Quatre échantillons.

Ainsi que cela arrive presque toujours avec les *Ophiernus*, les exemplaires recueillis par la *Scotia* sont en mauvais état. Sur trois d'entre eux, tous les bras sont cassés au ras du disque et le quatrième n'a conservé que quelques articles ; le disque est plus ou moins déformé, les boucliers radiaux sont cassés, etc. L'exemplaire qui a le moins souffert est représenté Pl. XI. figs. 102 et 103 : c'est celui que je décrirai ci-dessous. Le diamètre de son disque est de 13 millim. ; chez les autres, ce diamètre atteint 18 millim. dans le plus grand et 11·5 dans le plus petit.

Le disque est pentagonal, non excavé dans les espaces interbrachiaux. La face dorsale offre des plaques petites, mais bien distinctes, non imbriquées et devenant un peu plus grosses vers les boucliers radiaux et le bord du disque. Ces plaques portent de petits granules peu nombreux et épars, arrondis et qui deviennent plus serrés vers les boucliers radiaux. Dans cet exemplaire et dans deux autres, les plaques du disque sont égales et toutes très petites, mais dans le quatrième, on remarque un certain nombre de plaques plus grandes, arrondies, qui sont entourées par d'autres beaucoup plus petites qu'elles, ainsi que cela arrive chez les *Ophiocten*. Les boucliers radiaux sont très grands, ovalaires, plus longs que larges et séparés sur toute leur longueur par quelques rangées de plaques.

La face ventrale offre des plaques fines, égales, imbriquées, devenant plus grandes le long de la fente génitale : celles-ci sont étroites et allongées.

Les boucliers buccaux sont assez grands, aussi longs que larges, avec un angle proximal obtus et arrondi, des bords latéraux un peu convexes et un côté distal offrant en son milieu un lobe plus ou moins accentué et proéminent dans l'espace interbrachial. Les plaques adorales sont très étroites, allongées, amincies en dedans, mais cependant contiguës sur la ligne médiane, et très élargies en dehors : elles séparent la première plaque brachiale latérale du bouclier buccal. Les plaques orales sont hautes et assez larges. Il existe cinq papilles buccales latérales, obtuses, un peu inégales mais sans forme bien définie, et une papille terminale impaire, conique, plus grande que les voisines.

Les plaques brachiales dorsales qui sont conservées sont quadrangulaires, beaucoup plus larges que longues, avec les côtés proximal et distal parallèles et les bords latéraux peu divergents.

La première plaque ventrale est petite et triangulaire. Les suivantes sont grandes, quadrangulaires, avec le bord proximal étroit et le bord distal large et offrant un petit lobe médian ; les angles latéraux sont pointus et les bords latéraux, divergents, sont largement excavés par les pores tentaculaires. Elles sont contiguës.

Les plaques brachiales latérales, grandes, portent sur leur bord distal quatre piquants subégaux et courts ; ce nombre diminue sans doute sur les articles suivants. Les bras ne sont pas élargis en dedans du disque.

Les pores tentaculaires buccaux, largement ouverts dans la bouche comme d'habitude, offrent trois écailles distales. Les pores de la deuxième paire portent aussi trois écailles distales. Les pores suivants n'ont plus que deux écailles qui passent progressivement sur le bord externe, puis sur le bord proximal.

*Rapports et Différences.*—L'*O. quadrispinus* diffère surtout des autres espèces du genre par ses piquants brachiaux au nombre de quatre à la base des bras; elle est également caractérisée par les plaques dorsales du disque plus grandes et plus distinctes et par les granules moins nombreux que dans les autres espèces.

*Amphilepis antarctica*, nov. sp. (Pl. XIII. fig. 113 et 114.)

Août 1903, Baie de la Scotia, Orcades du Sud; profondeur 9–10 brasses. Un seul échantillon.

Diamètre du disque, 2·5 millim. Les bras n'ont guère que 6 millim. de longueur.

Le disque est subpentagonal. La face dorsale est couverte de très grandes plaques, peu nombreuses et polygonales, parmi lesquelles on ne reconnait pas de plaques primaires distinctes. Les boucliers radiaux ne sont pas plus grands que les plus grandes plaques du disque : ils sont triangulaires, à peu près aussi longs que larges et séparés sur toute leur longueur par une série de deux grandes plaques.

La face ventrale est recouverte de plaques inégales, polygonales-arrondies, peu ou pas imbriquées. Les fentes génitales sont étroites mais bien distinctes.

Les boucliers buccaux sont plutôt petits, triangulaires, avec le bord distal arrondi; ils sont à peu près aussi longs que larges. Les plaques adorales sont allongées, très élargies en dehors, rétrécies en dedans et contiguës. Les plaques orales sont assez épaisses et un peu allongées. La papille buccale externe est large et rectangulaire comme chez les *Amphipholis*, la suivante est petite et conique; la papille impaire est un peu plus grande.

Les plaques brachiales dorsales sont extrêmement grandes et larges et elles occupent la presque totalité de la face dorsale des bras, à l'exclusion des plaques latérales qui sont très petites. Elles ont un angle proximal très obtus, un bord distal extrêmement convexe et les angles latéraux arrondis.

La première plaque brachiale ventrale est petite, pentagonale, rétrécie dans sa partie distale entre les deux plaques adorales et beaucoup plus longue que large. Les suivantes sont pentagonales, grandes, plus longues que larges, avec un angle proximal obtus et le côté distal presque droit; elles se séparent vers la septième ou la huitième.

Les plaques brachiales latérales portent trois piquants.

L'orifice du pore tentaculaire buccal offre une petite écaille conique, à pointe obtuse. Les pores brachiaux portent chacun une petite écaille conique et à pointe obtuse également.

*Rapports et Différences.*—L'*A. antarctica* se distingue des autres espèces du genre par ses pores tentaculaires tous munis d'une petite écaille et par la grosseur des plaques brachiales dorsales.

*Amphiura magnifica*, nov. sp. (Pl. XII. fig. 111 ; Pl. XIII. fig. 119.)

9 Avril 1904, 51° 7′ lat. S., 9° 31′ long. W. ; profondeur 2103 brasses. Un échantillon de grande taille.

21 Mars 1904, 69° 33′ lat. S., 15° 19′ long. W. ; profondeur 2620 brasses. Un échantillon.

Cette espèce atteint une taille remarquable pour une *Amphiura*, et, dans le plus grand exemplaire, le diamètre du disque n'est pas inférieur à 18 millim. ; les bras sont cassés à une certaine distance de leur base, mais ils devaient atteindre une dizaine de centimètres de longueur. Dans l'autre échantillon, le disque, qui est en mauvais état, est plus petit et son diamètre n'est que de 15 millim.

Le disque est arrondi ; la face dorsale est bombée et la face ventrale plane ; le bord est épais et arrondi. La face dorsale est couverte de plaques assez petites, subégales et imbriquées, devenant un peu plus grandes vers les boucliers radiaux et plus petites vers la périphérie du disque. Les plaques primaires forment une rosette distincte : la plaque centro-dorsale est arrondie ; les radiales, qui sont séparées d'elle par cinq ou six rangées de plaques, sont un peu plus petites et élargies transversalement. Les boucliers radiaux sont petits, presque demi-circulaires, une fois et demie plus longs que larges, peu ou pas divergents et séparés sur toute leur longueur par une rangée de plaques ; leur longueur est égale au quart du rayon du disque.

La face ventrale est couverte de plaques très petites, fines et imbriquées. Les fentes génitales sont étroites.

Les boucliers buccaux sont petits, un peu plus longs que larges, triangulaires, avec un bord distal convexe et offrant en son milieu une proéminence large plus ou moins marquée ; l'angle proximal est aigu et les bords latéraux sont droits. Les plaques adorales sont larges et épaisses, triangulaires, avec les angles arrondis et le bord proximal un peu irrégulier ; les angles internes ne sont pas contigus. Les plaques orales sont très petites. Les papilles buccales latérales, au nombre de quatre, sont obtuses, carrées et elles augmentent légèrement de taille depuis l'externe jusqu'à l'interne : l'externe est portée par la plaque adorale et la suivante se trouve généralement au point de réunion de la plaque orale et de la plaque adorale.

Les plaques brachiales dorsales sont extrêmement larges et courtes, quatre fois plus larges que longues, et elles recouvrent presque toute la surface dorsale du bras ; elles offrent un angle distal tellement obtus qu'il fait presque 180° ; le bord distal est convexe et il rejoint par un bord recourbé les côtés de l'angle proximal. Ces plaques se séparent par un léger intervalle à une certaine distance de la base du bras. Elles sont parfois divisées par un sillon longitudinal et même morcelées en deux ou trois fragments.

La première plaque brachiale ventrale est assez petite, carrée ou trapézoïdale, aussi longue que large. Les suivantes sont pentagonales, avec un angle proximal obtus, tronqué sur les deux ou trois premières plaques, des bords latéraux droits et un côté distal arrondi se reliant par des angles également arrondis aux bords latéraux. Elles sont un peu plus larges que longues et toutes contiguës.

Les plaques latérales, peu proéminentes, portent trois piquants coniques dont la longueur est à peu près égale à celle de l'article ; le médian est un peu plus grand.

L'écaille tentaculaire, unique, est allongée et sa longueur égale presque celle des côtés de la plaque ventrale ; ses bords sont parallèles et son extrémité est obtuse.

*Rapports et Différences.*—L'*A. magnifica* appartient à la section *Amphioplus* caractérisée par la présence de quatre papilles buccales. Elle se distingue facilement des espèces de cette section qui n'ont qu'une seule écaille tentaculaire, car presque toutes ont plus de trois piquants brachiaux, sauf l'*A. dalea* Lyman : mais cette dernière espèce a les boucliers radiaux plus grands, une forme différente des papilles buccales et l'écaille tentaculaire est portée par la plaque brachiale ventrale.

*Amphiura Mortenseni*, nov. sp. (Pl. XIV. fig. 121 et 122.)

Avril 1903, Baie de la Scotia, Orcades du Sud ; profondeur 9–10 brasses. Quelques échantillons.

26 Janvier 1904, Baie Jessie, Orcades du Sud. Trois échantillons.

Diamètre du disque, 5 à 6 millim. ; longueur des bras, 25 à 30 millim.

Le disque est arrondi, subpentagonal. La face dorsale est recouverte de plaques de moyenne grosseur, parmi lesquelles on distingue généralement une rosette de plaques primaires plus grandes ; la centro-dorsale est arrondie, les radiales, aussi grandes qu'elle, sont arrondies ou élargies transversalement : elles ne sont séparées les unes des autres et de la centro-dorsale que par un seul rang de petites plaques. On reconnait, en outre, dans les espaces radiaux, une ou deux plaques plus grandes, la dernière placée entre les extrémités proximales des boucliers radiaux. Dans les espaces interradiaux, on remarque aussi deux plaques plus grandes, dont la dernière reste à une certaine distance du bord du disque. Les autres plaques sont petites, imbriquées et subégales. Les boucliers radiaux sont petits, demi-circulaires, deux fois plus longs que larges, avec le bord interne droit et le bord externe très convexe ; ils sont divergents, rapprochés en dehors mais séparés par une petite plaque ; en dedans ils sont séparés par deux ou trois rangs de plaques. Leur longueur est un peu supérieure au tiers du rayon du disque.

La face ventrale est couverte de plaques imbriquées, petites et égales. Les fentes génitales sont étroites.

Les boucliers buccaux sont un peu plus longs que larges : ils offrent une partie principale triangulaire, avec un angle proximal obtus et arrondi, limité par deux côtés convexes, et un lobe distal large et plus ou moins proéminent dans l'espace

interradial. Les plaques adorales sont allongées et très grandes, rétrécies en dedans et se terminant par un angle arrondi qui est contigu à son congénère ; elles sont fortement élargies en dehors. Les plaques orales sont un peu allongées et étroites. Il existe une papille buccale externe, courte, forte, conique et pointue, et une interne allongée, cylindrique, épaisse, à pointe obtuse ; entre les deux, on peut observer, sur un plan supérieur, une papille plus mince, plus petite et pointue.

Les plaques brachiales dorsales sont très grandes et larges, presque biconvexes, avec un bord proximal très court qui, à une certaine distance de la base disparait et fait place à un angle très obtus, des bords latéraux petits et parfois indistincts et un côté distal fortement convexe. Elles sont contiguës.

La première plaque brachiale ventrale est petite et rétrécie dans sa région distale par les plaques adorales qui lui sont adjacentes : elle présente un bord proximal convexe et deux côtés concaves ; le bord distal est très réduit. Les suivantes sont grandes, pentagonales, avec un angle proximal très obtus, parfois même atteignant près de 180°, ce qui rend les plaques presque rectangulaires et un côté distal presque droit se reliant par des angles arrondis aux bords latéraux qui sont droits ; elles sont un peu plus longues que larges et toutes contiguës.

Les plaques latérales portent quatre piquants subégaux et dont la longueur atteint celle de l'article : ils sont épais et forts, à pointe obtuse.

Les pores tentaculaires sont munis de deux écailles de moyenne grosseur, un peu coniques et disposées à angle droit.

*Rapports et Différences.*—L'*A. Mortenseni* appartient à la section des *Amphiura* s. str. et elle se caractérise facilement par la forme de ses boucliers buccaux munis d'un lobe distal proéminent et bien accentué.

On ne peut la confondre avec les autres espèces du même groupe qui ont la face ventrale couverte de plaques et deux écailles tentaculaires : l'*A. Eugeniæ* a trois papilles buccales et doit rentrer dans le groupe *Amphiodia* ; quant à l'*A. Studeri* Lyman (*A. antarctica* Studer), elle a les boucliers buccaux pentagonaux et plus longs que larges.

*Amphiura consors*, nov. sp. (Pl. XIII. fig. 117 et 118.)

21 Mars 1904, 69° 33′ lat. S., 15° 19′ long. W. ; profondeur 2620 brasses. Deux échantillons.

Dans le plus grand exemplaire, le diamètre du disque est de 12 millim. et l'un des bras, qui est à peu près entier, atteint 55 millim. de longueur ; dans l'autre individu, le diamètre du disque est de 10 millim. seulement.

Le disque est arrondi, très légèrement échancré à la base des bras. La face dorsale est couverte de plaques petites, presque arrondies, à peu près aussi longues que larges, ne s'imbriquant qu'au voisinage du bord du disque : les trois ou quatre plaques périphériques qui se trouvent immédiatement en dehors de chaque bouclier radial sont

notablement plus grandes et plus longues que les autres. A la périphérie du disque, les plaques s'arrêtent brusquement à une bordure qui est constituée par des plaques beaucoup plus petites. Les boucliers radiaux, plutôt petits, sont une fois et demi plus longs que larges, avec un bord distal étroit, un bord externe convexe un peu irrégulier et un côté interne droit ; ils sont légèrement divergents et rapprochés en dehors, où ils ne sont séparés que par une seule plaque, tandis qu'en dedans ils sont séparés par deux ou trois plaques. On distingue une rosette de six plaques primaires, mais très dissociées, les radiales se trouvant à une grande distance de la centro-dorsale. Ces plaques primaires sont très petites dans le grand exemplaire ; elles sont plus grandes et plus rapprochées dans le petit.

La face ventrale du disque est couverte de plaques très fines et imbriquées. Les fentes génitales sont étroites.

Les boucliers buccaux sont petits, triangulaires, à peu près aussi longs que larges ou un peu plus larges que longs : ils ont l'angle proximal assez ouvert, les côtés droits et le bord distal un peu convexe. Les plaques adorales, de moyenne grosseur, sont très élargies en dehors et elles se touchent à peine par leur sommet interne qui est émoussé. Les plaques orales sont petites, plus hautes que larges. Les papilles buccales latérales sont au nombre de quatre : elles sont petites, obtuses et carrées ; la papille externe est un peu plus grande et plus allongée que les autres.

Les plaques brachiales dorsales sont extrêmement larges et leur angle proximal est tellement obtus qu'il atteint presque 180° ; le bord distal est convexe et il rejoint, par deux petits bords latéraux, les deux côtés de l'angle proximal. Ces plaques sont quatre fois plus longues que larges et recouvrent même un peu les faces latérales du bras ; elles sont très légérement séparées dès la base.

La première plaque brachiale ventrale est extrêmement réduite et elle est resserrée entre les plaques adorales : elle est pentagonale. Les suivantes sont grandes et pentagonales, avec un angle proximal obtus qui est tronqué sur les premières, des bords latéraux grands et droits, et un côté distal convexe ; elles sont un peu plus longues que larges et toutes contiguës.

Les piquants brachiaux sont au nombre de trois et leur longueur est à peu près égale à celle de l'article : le piquant médian est toutefois un peu plus long que les autres ; tous sont coniques et pointus.

Les pores tentaculaires sont grands et complètement dépourvus d'écaille tentaculaire.

*Rapports et Différences.*—L'*A. consors* rappelle beaucoup l'*A. magnifica*, que j'ai décrite ci-dessus, par les plaques dorsales du disque, par la forme des plaques brachiales dorsales et par le nombre des piquants, mais elle s'en écarte immédiatement par l'absence d'écaille tentaculaire et par la forme des boucliers buccaux.

Les *Amphiura* de la section *Amphioplus* qui n'ont point d'écaille tentaculaire sont extrêmement peu nombreuses, et je ne connais, parmi elles, que les *A. trepida* Koehler, et *Verrillii* Lyman, espèces avec lesquelles l'*A. consors* ne peut être confondue.

### *Amphiura tomentosa*, Lyman.

LYMAN, *Reports of the "Challenger": Ophiuroidea*, 1882, p. 132, pl. xxix. fig. 10–12.

Août 1903, Baie de la Scotia, Orcades du Sud ; profondeur 9 à 10 brasses. Deux échantillons.

Le diamètre du disque varie entre 3 et 2·5 millim.

Ces exemplaires ne sont pas tout à fait conformes à la description de LYMAN, mais je pense que cela tient au jeune âge des sujets, car chez le type de LYMAN le diamètre du disque est de 6·5 millim. La papille buccale externe est saillante, conique et pointue, au lieu d'être courte, et les boucliers radiaux sont un peu élargis ; enfin les plaques brachiales dorsales sont très développées, presque aussi longues que larges et plus longues que dans le type de LYMAN. Celui-ci provenait de Kerguelen.

Si les différences que je signale entre les individus des Orcades et ceux de Kerguelen se retrouvaient chez l'adulte, il y aurait sans doute lieu de considérer les premiers comme constituant une variété distincte du type de LYMAN.

### *Amphiura magellanica*, Ljungmann. (Pl. XI. fig. 104.)

Voir pour la bibliographie :

LUDWIG, "Ophiuroideen," *Hamburger Magalhaensischen Sammelreise*, 1899, p. 10.
LUDWIG, "Asterien und Ophiuren der schwedischen Expedition," *Zeit. f. wiss. Zool.*, Bd. lxxxii., 1905, p. 75.

23 Avril 1904, île Gough ; profondeur 75 brasses. Deux échantillons.

Diamètre du disque, 2·5 millim.

Cette espèce n'a jamais été représentée : je donne ici un dessin de la face ventrale, très caractéristique à cause de la forme du premier piquant ventral, qui s'allonge progressivement jusqu'au septième ou huitième article.

### *Amphiura squamata* (Delle Chiaje).

23 Avril 1904, île Gough ; profondeur 75 brasses. Un échantillon de très petite taille : le diamètre du disque ne dépasse pas 2 millim.

Cet exemplaire ne diffère pas du type ordinaire de l'*A. squamata*, dont l'aire de dispersion géographique est très vaste, ainsi qu'on le sait (voir LUDWIG, "Ophiuroideen," *Hamburger Magalhaensische Sammelreise*, p. 19).

*Ophiactis asperula* (Philippi).

Voir pour la bibliographie :

Ludwig, "Die Ophiuren der Sammlung Plate," *Zool. Jahrb.*, Suppl. Bd., 1898, p. 752.
Ludwig, "Ophiuroideen," *Hamburger Magalhaensische Sammelreise*, 1899, p. 6.
Ludwig, "Asterien und Ophiuren der schwedischen Expedition," *Zeit. f. wiss. Zool.*, Bd. lxxxii., 1905, p. 74.
Koehler, "Révision des Ophiures du Muséum," *Bull. Scientif.*, 1907, p. 100.

1er Décembre 1903, banc de Burdwood, 54° 25′ lat. S., 57° 32′ long. W. ; profondeur 56 brasses. Quelques échantillons.

*Ophiacantha Valenciennesi*, Lyman.

Voir pour la bibliographie :

Koehler, *Ophiures de l'Expédition du "Siboga" : Ophiures de mer profonde*, 1904, p. 110.
Koehler, *Expéditions scientifiques du "Travailleur" et du "Talisman" : Ophiures*, 1906, p. 292.

23 Avril 1904, île Gough ; profondeur 100 brasses. Deux échantillons.

Dans l'un des individus, le diamètre du disque est de 11·5 millim., l'autre est très petit et le diamètre de son disque ne dépasse pas 5 millim.

Ces deux individus sont bien conformes au type de l'espèce et une seule papille buccale externe est élargie.

L'*O. Valenciennesi* possède une extension géographique très vaste : le *Challenger* l'a découverte par 5° 42′ lat. S. et 132° 25′ long. E. ; le *Siboga* l'a retrouvée dans l'Archipel de la Sonde, le *Travailleur* et la *Princesse Alice* dans l'Atlantique Nord. Les observations de la *Scotia* montrent que cette Ophiure peut descendre jusque vers le 40° lat. S.

*Ophiacantha frigida*, nov. sp. (Pl. XIV. fig. 123 à 125.)

18 Mars 1903, 62° 10′ lat. S., 41° 20′ long. W. ; profondeur 1775 brasses. Trois échantillons.

18 Mars 1904, 71° 22′ lat. S., 16° 34′ long. W. ; profondeur 1410 brasses. Plusieurs échantillons qui me sont arrivés dans un bocal cassé : ils se trouvaient desséchés et en même temps couverts d'une vase très adhérente.

Le diamètre du disque atteint 13 millim. dans quelques très gros individus, mais ne dépasse habituellement pas 8 ou 10 millim. Les bras sont à peu près tous cassés ; les plus longs arrivent à 45 millim. de longueur.

Le disque est arrondi ou subpentagonal. La face dorsale est complètement couverte

de petits piquants minces et cylindriques, offrant quelques rares denticulations sur leur bords, et, à l'extrémité, deux ou trois spinules allongées (fig. 125). Ces piquants sont très serrés et l'on n'aperçoit les écailles sous-jacentes, qui sont très fines, que dans les endroits où ils sont tombés. Les boucliers radiaux, qui sont complètement couverts par ces piquants, ne sont pas visibles : ils sont petits et largement séparés.

La face ventrale est couverte de piquants identiques à ceux de la face dorsale, mais qui vont en diminuant au fur et à mesure qu'on se rapproche des boucliers buccaux. Les fentes génitales sont larges.

Les boucliers buccaux, de moyennes dimensions, sont élargis et triangulaires, avec un angle proximal aigu, des bords latéraux un peu concaves et un côté distal convexe offrant, en son milieu, un lobe plus ou moins proéminent, dont la présence donne souvent au bouclier une forme losangique. Les plaques adorales sont assez fortes et longues, élargies en dehors et formant un lobe qui sépare la première plaque brachiale latérale du bouclier buccal. Les plaques orales sont triangulaires, de dimensions moyennes. Les papilles buccales latérales sont au nombre de trois : l'interne est conique, la deuxième un peu plus forte, l'externe encore plus grosse et très souvent épaissie, au moins à la base ; la papille terminale impaire est grande et conique.

Les plaques brachiales dorsales sont assez grandes, triangulaires, avec le bord distal convexe, un peu plus larges que longues : elles sont séparées dès la première.

La première plaque brachiale ventrale est petite, pentagonale. Le deuxième est triangulaire avec un angle proximal tronqué. Les suivantes sont grandes, triangulaires, avec un angle proximal très obtus et un bord distal fortement convexe. Elles sont séparées à partir de la deuxième.

Les plaques latérales, assez proéminentes, portent huit piquants qui paraissent lisses à l'œil nu, mais qui, au microscope, se montrent couverts de petites rugosités très fines. Les piquants du premier article sont parfois un peu rapprochés de la ligne médiane dorsale, mais ils ne forment jamais une rangée continue. La longueur augmente depuis le premier ventral, qui est un peu plus long que l'article, jusqu'au septième, dont la longueur est presque égale à trois articles au commencement du bras ; le huitième est un peu plus court. Sur les articles suivants, la longueur diminue et le piquant le plus long ne dépasse pas deux articles.

Les pores tentaculaires de la première paire sont gros et ils montrent parfois deux écailles coniques : je n'observe pas ces deux écailles sur tous les individus, mais je pense que l'une d'elles a pu tomber accidentellement, ou à la suite du brossage que j'ai dû faire pour dégager les échantillons de la vase qui les recouvrait. Les pores suivants n'ont qu'une seule écaille, qui est assez allongée et pointue.

*Rapports et Différences.*—L'*O. frigida* se rapproche de l'*O. bidentata* Retzius, des mers du Nord, qu'elle rappelle par l'épaississement de la papille buccale externe : celle-ci

est plus forte cependant que chez l'*O. bidentata* ; elle diffère aussi de cette espèce par les deux écailles sur les pores tentaculaires de la première paire, par les plaques brachiales dorsales plus grandes, et enfin par la présence de véritables piquants sur le disque.

L'*O. frigida* offre aussi quelques analogies avec l'*O. cosmica* Lyman, que la *Scotia* a draguée plus au Nord : elle en diffère par sa taille notablement plus petite, par l'absence de piquants sur les deux premières plaques brachiales dorsales, par l'absence de papilles buccales supplémentaires, par les piquants de la face dorsale du disque plus longs, etc.

*Ophiacantha opulenta*, nov. sp. (Pl. XIV. fig. 128 et 129.)

18 Mars 1903, 62° 10′ lat. S., 41° 20′ long. W. ; profondeur 1775 brasses. Un seul échantillon.

L'exemplaire est à peu près exclusivement réduit au disque, les bras, au nombre de sept, étant tous cassés à leur base. Cette circonstance est d'autant plus regrettable que l'espèce est très particulière.

Le disque est assez épais et son diamètre atteint 13 millim. ; il est échancré dans les espaces interradiaux. La face dorsale est bombée. Elle présente sept paires de côtes saillantes, larges et très accusées, qui atteignent presque le centre du disque vers lequel elles convergent : elles sont plus larges en dehors et l'on retrouve vers leur extrémité distale les boucliers radiaux qui sont fins et allongés, deux fois et demi plus longs que larges. La surface du disque est couverte de petits bâtonnets courts, épais et rugueux à l'extrémité qui peut même offrir des spinules très petites. On distingue nettement les plaques légèrement imbriquées qui portent ces bâtonnets et qui sont fines et arrondies : chaque plaque porte un bâtonnet. On retrouve ces mêmes plaques sur les côtes radiales, mais les bâtonnets manquent généralement ; ils existaient cependant, car on reconnait parfaitement leurs cicatrices.

La face ventrale du disque porte des bâtonnets identiques à ceux de la face dorsale, mais plus courts. Les fentes génitales sont étroites.

Les boucliers buccaux sont triangulaires, avec un angle proximal qui se prolonge en une pointe plus ou moins aiguë, les côtés un peu concaves et un bord distal convexe offrant un petit lobe en son milieu. Les plaques adorales sont assez épaisses, courtes, à bords presque parallèles ; elles sont deux fois plus longues que larges : elles sont contiguës en dedans et en dehors elles ne séparent pas le bouclier buccal de la première plaque brachiale latérale. Les plaques orales sont hautes. Les papilles buccales latérales sont généralement au nombre de cinq : les quatre externes sont fortes et obtuses, l'interne est plus allongée, plus mince et pointue, à peu près deux fois plus longue que les autres. La papille terminale impaire est également longue, mince et pointue ; elle forme avec ses deux voisines un faisceau qui termine les mâchoires et se dirige vers le centre de la bouche, donnant à celle-ci un aspect caractéristique.

Les bras sont cassés tout près du disque ; les deux ou trois premières plaques brachiales dorsales qui sont conservées sont rectangulaires et plus larges que longues.

La première plaque brachiale ventrale est grande, triangulaire avec le bord distal convexe, celui-ci se décomposant parfois en deux côtés limitant un angle obtus : elle est un peu plus longue que large. Les suivantes sont triangulaires, avec l'angle proximal très obtus et le bord distal fortement convexe. Elles sont séparées dès la seconde.

Je ne vois que deux ou trois piquants ventraux sur les articles conservés : ces piquants sont plus courts que l'article, assez épais, cylindriques, à extrémité obtuse ; les piquants dorsaux sont enlevés.

L'écaille tentaculaire est assez petite, conique et obtuse.

*Rapports et Différences.*—L'*O. opulenta* présente un facies bien particulier, et, par sa face dorsale munie de côtes saillantes, elle ressemble à une Cladophiure. Mais elle appartient bien au genre *Ophiacantha* et elle se distingue facilement des autres espèces de ce genre qui possèdent plus de cinq bras par ses côtes radiales très développées et par l'allongement des trois papilles buccales proximales.

### *Ophiacantha cosmica*, Lyman.

*Ophiacantha cosmica*, Lyman, *Reports of the "Challenger": Ophiuroidea*, p. 194, pl. xiii. fig. 13–15.

*Ophiacantha cosmica*, Lütken et Mortensen, "The Ophiuridæ off the W. Coast of Mexico and off the Galapagos Islands," *Mem. Mus. Comp. Zool.*, vol. xxiii., No. 2, 1899, p. 166, pl. xv. fig. 13.

10 Mars 1903, 66° 40′ lat. S., 40° 35′ long. W. ; profondeur 2425 brasses. Un échantillon.

29 Avril 1904, 39° 48′ lat. S., 2° 33′ long. E. ; profondeur 2645 brasses. Deux échantillons de grande taille.

Dans les deux plus grands exemplaires, le diamètre du disque atteint 16 et 17 millim. et les bras ont une longueur de 90 millim. dans le plus grand. Ces dimensions sont voisines de celles qu'indique Lyman. Dans l'un des grands individus, les bâtonnets de la face dorsale du disque sont très courts, fins et espacés, tandis que dans les autres, ils sont plus grands, plus forts et plus nombreux, et conformes à la description de Lyman. Les papilles buccales supplémentaires sont très irrégulières : sur un exemplaire, j'en trouve, dans un radius, jusqu'à quatre sur l'extrémité des plaques orales, tandis que dans un autre je n'en observe qu'une seule en tout. Les pores tentaculaires buccaux sont parfois très grands et ils portent souvent deux écailles, chiffre indiqué par Lütken et Mortensen, tandis que Lyman n'en mentionne qu'une.

Lütken et Mortensen ont complété ou rectifié la description de Lyman sur quelques points et les bâtonnets de la face dorsale du disque ont bien la forme qu'ils indiquent, sauf sur l'individu mentionné plus haut, où ces bâtonnets sont petits et épars.

J'observe, sur mes échantillons, que les plaques brachiales ventrales sont très grandes, avec le bord distal convexe. Les plaques dorsales sont aussi plus larges que sur les dessins de LYMAN et des auteurs danois. Les deux premières plaques brachiales dorsales offrent seules des piquants qui se trouvent presque tous vers le bord distal de la plaque: il y en a aussi parfois sur la plaque elle-même. En somme, il y a quelques variations, comme celles que LYMAN a déjà signalées.

L'*O. cosmica* a une très grande extension géographique. Le *Challenger* l'a rencontrée dans des localités comprises entre le 2° et le 62° lat. S. et à des longitudes de 45°, 123°, 144° E. et 74° W., par des profondeurs variant de 350 à 2225 brasses. L'*Albatross* a retrouvé l'*O. cosmica* dans le Pacifique Nord, entre le 6° et le 10° lat. N. d'une part et les 82°–96° long. W., à des profondeurs comprises entre 1672 et 2232 brasses. On a vu plus haut que la *Scotia* avait rencontré l'*O. cosmica* dans deux stations assez éloignées l'un de l'autre.

### *Ophiacantha vivipara*, Ljungmann.

Voir pour la bibliographie :

LUDWIG, "Ophiuroideen," *Hamburger Magalhaensische Sammelreise*, 1899, p. 13.
KOEHLER, "Révision des Ophiures du Muséum," *Bulletin Scientifique*, 1907, p. 321.

1er Décembre 1903, banc de Burdwood, 54° 25′ lat. S., 57° 32′ long. W.; profondeur 56 brasses. Six échantillons, tous à six bras et la plupart portant des jeunes.

### *Ophiotrema Alberti*, Koehler.

Voir pour la bibliographie :

KOEHLER, *Expéditions Scientifiques du "Travailleur" et du "Talisman": Ophiures*, 1906, p. 295.

9 Avril 1904, 51° 7′ lat. S., 9° 31′ long. W.; profondeur 2103 brasses. Un seul échantillon en mauvais état.

Diamètre du disque, 17 millim. Un seul bras est conservé sur une longueur de 15 millim.; les autres sont cassés à la base. La face dorsale du disque manque en grande partie.

A part de très légères différences dans la forme des plaques brachiales dorsales, qui sont plus exactement losangiques, et des plaques ventrales qui ont le bord distal légèrement échancré, cet exemplaire se rapporte aux échantillons de l'Atlantique Nord que j'ai étudiés. Les spécimens de la *Princesse Alice* et du *Travailleur* sont eux-mêmes en assez mauvais état, et comme la *Scotia* n'a recueilli qu'un individu unique assez mal conservé, les comparaisons sont difficiles. En tout cas, il est incontestable que cet individu est extrêmement voisin des exemplaires trouvés dans l'Atlantique boréal, et, jusqu'à preuve du contraire, je le considère comme appartenant à la même espèce.

*Ophiomitrella ingrata.* (Pl. XIV. fig. 126 et 127.)

23 Avril 1904, île Gough ; profondeur 100 brasses. Quelques échantillons.

Tous les exemplaires sont de petite taille et le diamètre du disque ne dépasse pas 4 millim. dans les plus grands. Les bras sont moniliformes, plus ou moins contournés, ce qui fait que leur longueur exacte ne peut être évaluée, mais ils sont courts.

Le disque est arrondi. La face dorsale offre de grandes plaques, irrégulièrement polygonales ou arrondies, imbriquées vers les bords du disque ; chacune d'elles porte en son centre un gros granule allongé, rugueux et arrondi à l'extrémité. Toutes les plaques paraissent munies de ce granule, et, quand il manque, on peut reconnaître la cicatrice qui indique son insertion. Les boucliers radiaux, de moyenne grosseur, sont irrégulièrement triangulaires, avec les angles et les bords arrondis ; ils sont aussi longs que larges, fortement divergents et contigus ou très rapprochés en dehors. La face ventrale est couverte de plaques plus petites que sur la face dorsale, imbriquées et dépourvues de granules. Les fentes génitales sont larges.

Les boucliers buccaux, de taille moyenne, sont un peu plus larges que longs et parfois aussi longs que larges ; ils sont triangulaires ou losangiques suivant que leur bord distal offre en son milieu un renflement plus ou moins proéminent ; l'angle proximal est assez ouvert et limité par des côtés droits. Les plaques adorales sont assez grandes, plus larges en dehors qu'en dedans, et elles séparent le bouclier buccal de la première plaque brachiale latérale. Les plaques orales sont triangulaires. Les papilles buccales latérales, au nombre de trois, sont grandes, cylindriques, à surface rugueuse et leur extrémité obtuse offre même quelques petites spinules. La papille terminale impaire n'est pas beaucoup plus forte que les autres.

Les deux ou trois premières plaques brachiales dorsales sont quadrangulaires, élargies transversalement, beaucoup plus larges que longues. Les suivantes sont grandes, triangulaires, avec le bord distal fortement convexe ; elles sont un peu plus larges que longues et largement séparées.

La première plaque brachiale ventrale est assez grande et pentagonale ou quadrangulaire, avec un bord distal large et arrondi. Les suivantes sont grandes, pentagonales, avec un angle proximal obtus, les bords latéraux droits et le côté distal d'abord convexe ; au delà du disque, ce côté offre une légère échancrure en son milieu.

Les plaques latérales, proéminentes, portent cinq piquants assez gros, cylindriques, obtus et couverts de très fines denticulations : ils sont plutôt courts, car le premier ventral égale à peine l'article et le dernier n'atteint pas un article et demi. Les séries dorsales sont largement séparées à la base des bras.

L'écaille tentaculaire est assez grande, conique et pointue.

*Rapports et Différences.*—L'*O. ingrata* est voisine de l'*O. cordifera* Koehler, de l'Atlantique boréal ; elle en diffère par les plaques dorsales du disque plus petites et plus nombreuses, portant chacune un granule beaucoup plus petit ; les piquants brachiaux sont aussi moins nombreux, plus gros et obtus à l'extrémité.

*Ophiomyxa vivipara*, Studer.

Voir pour la bibliographie :

Ludwig, "Die Ophiuren der Sammlung Plate," *Zool. Jahrb.*, Suppl. Bd. iv., 1898, p. 768.
Ludwig, "Ophiuroideen," *Hamburger Magalhaens. Sammelreise*, Hamburg, 1899, p. 9.
Ludwig, "Asterien und Ophiuren der schwedischen Expedition," *Zeit. f. wiss. Zool.*, Bd. lxxxii. p. 76.
Koehler, "Révision des Ophiures du Muséum d'histoire naturelle," *Bulletin scientifique*, 1907, p. 341.

1er Décembre 1903, banc de Burdwood, 54° 25′ lat. S., 57° 32′ long. W. ; profondeur 56 brasses. Sept échantillons.

Dans les plus grands, le diamètre du disque est de 15 millim. ; les autres sont plus petits. Quelques individus que j'ai ouverts montrent des jeunes dans les bourses génitales.

? *Astrotoma Agassizi*, Lyman. (Pl. XIII. fig. 120.)

Voir pour la bibliographie :

Lyman, "Ophiuridæ and Astrophytonidæ," *Ill. Cat. Mus. Comp. Zool.*, No. 8, part 2, 1875, p. 24, pl. iv. fig. 57 et 58.
Lyman, *Reports of the "Challenger" : Ophiuroidea*, p. 272.

1er Décembre 1903, banc de Burdwood, 54° 25′ lat. S., 57° 32′ long. W. ; profondeur 56 brasses. Deux échantillons très jeunes.

C'est avec doute que je rapporte à l'*A. Agassizi* ces exemplaires, dont les caractères ne sont pas encore assez nets pour permettre une détermination précise. Dans le plus petit, le diamètre du disque n'est que de 4 millim. seulement et les bras ont 20 à 25 millim. de longueur. On aperçoit encore la rosette de plaques primaires qui est irrégulière ; la face dorsale du disque et des bras est couverte de gros granules. Dans l'autre, qui est un peu plus grand et dont le disque mesure 6·5 millim. de diamètre, les plaques primaires sont moins distinctes.

La plaque madréporique est bien apparente. Les pores tentaculaires de la première paire n'ont pas d'écaille et tous les pores suivants en ont deux, ainsi qu'on l'observe chez l'*A. Agassizi*.

*Gorgonocephalus chilensis* (Philippi).

Voir pour la bibliographie :

Ludwig, *Die Ophiuren der Sammlung Plate*, 1898, p. 775.
Ludwig, "Ophiuroideen," *Hamburger Magalhaensische Sammelreise*, 1899, p. 16.
Koehler, "Révision des Ophiures du Muséum," *Bull. scient. du Nord*, 1907, p. 100.

1er Décembre 1903, banc de Burdwood, 54° 25′ lat. S., 57° 32′ long. W. ; profondeur 56 brasses. Un petit exemplaire.

## ÉCHINIDES.

### *Stereocidaris canaliculata* (Agassiz).

Voir pour la bibliographie :

MEISSNER, *Hamburger Magalhaensischen Sammelreise : Echinoideen*, p. 3, 1900. L'auteur y range l'espèce dans le genre *Cidaris* et la réunit au *St. nutrix*.

MORTENSEN, *The Danish Ingolf Expedition*, vol. iv., part 1, 1903 : *Echinoidea*, p. 25, pl. viii. fig. 6, 8 et 32.

Janvier 1903, Port Stanley, îles Falkland ; profondeur 0–5 brasses. Une dizaine d'échantillons.

1er Décembre 1903, banc de Burdwood, 54° 25′ lat. S., 57° 32′ long. W. ; profondeur 56 brasses. Deux échantillons.

Les auteurs ont généralement confondu en une seule et même espèce les *St. canaliculata* Agassiz, et *nutrix* (Wyville Thomson). MORTENSEN a montré que ces deux formes étaient bien distinctes et que la première était particulière à la pointe méridionale de l'Amérique du Sud et la deuxième à Kerguelen. Les recherches de la *Scotia* confirment bien l'opinion du savant naturaliste danois et montrent que le *St. canaliculata*, non seulement se trouve dans les parages de la Terre de Feu, mais encore peut descendre beaucoup plus bas vers le Sud.

Le *St. canaliculata* est susceptible d'offrir des variations qui ont déjà été indiquées par AGASSIZ. Ainsi les exemplaires des îles Falkland ont les uns des piquants courts et les autres des piquants plus longs ; les deux individus du banc de Burdwood ont des piquants allongés. Je retrouve dans ces différentes formes les mêmes pédicellaires, identiques à ceux que MORTENSEN a décrits et figurés.

Les individus sont tous d'assez petite taille et leur diamètre est compris entre 20 et 25 millim., non compris les radioles. Aucun d'eux n'est en état de gestation, mais je remarque que certains échantillons ont l'appareil apical fortement déprimé : il en résulte ainsi la formation d'une sorte de fossette plus ou moins profonde qui peut évidemment servir de cavité incubatrice.*

* Pendant l'impression de mon mémoire, j'ai reçu l'important travail de L. CLARK sur les *Cidaridæ* (*Bull. Mus. Comp. Zool.*, vol. li., 1907, p. 7). Cet auteur range les deux *St. canaliculata* et *nutrix*, ainsi que *Sterocidaris Mortenseni* cité ci-dessous, dans un nouveau genre auquel il donne le nom d'*Austrocidaris* et qui est caractérisé par le petit nombre de tubercules qu'offre le système apical, la forme des piquants secondaires, etc. J'ai pu constater que, par la disposition des zones ambulacraires et interambulacraires, les exemplaires de la *Scotia* appartenaient au *St.* (*Austrocidaris*) *canaliculata* tel que l'entend L. CLARK.

### *Stereocidaris Mortenseni* (Koehler).

*Goniocidaris Mortenseni*, Koehler, *Résultats du Voyage de S.Y. "Belgica" : Échinides et Ophiures*, 1901, p. 5, pl. i. fig. 1, pl. ii. fig. 11, pl. iii. fig. 17, pl. iv. fig. 29, pl. v. fig. 30.
*Stereocidaris Mortenseni*, Mortensen, *The Danish Ingolf Expedition : Echinoidea*, part i., p. 27.

18 Mars 1904, 71° 22′ lat. S., 16° 34′ long. W. ; profondeur 1410 brasses. Un échantillon en excellent état.

Le diamètre du disque est de 30 millim. Tous les piquants sont conservés ; le plus grand atteint jusqu'à 76 millim. de longueur. Les piquants secondaires sont très développés surtout au dessus de l'ambitus ; ils sont allongés, cylindriques et quelque peu renflés vers l'extrémité.

J'ai retrouvé sur cet échantillon les pédicellaires globifères décrits et figurés par MORTENSEN.

Le test et les piquants sont d'un gris-brun clair ; les piquants sont gris, légèrement rosés à la base.

La profondeur à laquelle la *Scotia* a dragué cet Échinide est bien plus grande que celle où la *Belgica* l'avait rencontré.*

### *Notechinus magellanicus*, var. *neu-amsterdami*, Döderlein.

Voir pour la bibliographie :

DÖDERLEIN, *Echinoideen der deutschen Tiefsee Expedition*, 1906, p. 227, pl. xxvii. fig. 9, pl. xxviii. fig. 3–4, pl. xxxv. fig. 15, pl. xxxvii. fig. 5.

23 Avril 1904, île Gough ; profondeur 100 brasses. Trois échantillons.

Ces exemplaires appartiennent à la variété *neu-amsterdami* décrite par DÖDERLEIN. Ils sont de petite taille et leur diamètre varie entre 8 et 10 millim.

### *Sterechinus Neumayeri* (Meissner). (Pl. XVI. fig. 143 et 144.)

*Echinus Neumayeri*, Meissner, *Hamburger Magalhaensischen Sammelreise : Echinoideen*, p. 12.
*Sterechinus Neumayeri*, Mortensen, *The Danish Ingolf Expedition : Echinoidea*, p. 103, 106 et 107, pl. xix. fig. 14, pl. xx. fig. 7 et 11.
*Echinus margaritaceus*, Koehler, *Expédition Antarctique française du Dr. Charcot : Echinodermes*, 1906, p. 30, pl. i. fig. 9, pl. iii. fig. 29 et 30, pl. iv. fig. 40 et 43.
*Sterechinus Neumayeri*, Döderlein, *Echinoideen der deutschen Tiefsee Expedition*, p. 219.

Baie de la Scotia, Orcades du Sud ; profondeur 9 à 10 brasses. Quatre échantillons, dont les diamètres respectifs sont de 28, 45, 50 et 57 millim.

Ces exemplaires sont absolument identiques à ceux que l'Expédition Charcot a recueillis à l'île Both-Wandel et que j'ai décrits sous le nom d'*Echinus margaritaceus*.

* Dans son travail sur les *Cidaridæ*, L. CLARK range le *Stereocidaris Mortenseni* dans son nouveau genre *Austrocidaris*, mais avec quelque doute, parce qu'il ne connait pas la forme des piquants secondaires. Or, ainsi que je l'ai dit plus haut, ces piquants sont cylindriques et très légèrement renflés vers l'extrémité ; l'espèce peut donc parfaitement rentrer dans le genre *Austrocidaris*.

Je m'empresse de rectifier cette erreur, qui est assez excusable, si l'on songe, d'une part, que l'unique dessin donné par MEISSNER du *Sterechinus Neumayeri* représente un appareil apical anormal, d'autre part, que les pédicellaires des exemplaires que j'ai eus en mains ayant été attaqués par le formol, il m'avait été impossible de reconnaître leurs formes exactes, ainsi que je l'ai expliqué, et qu'enfin l'*Echinus margaritaceus* n'avait été décrit et figuré que d'une manière très imparfaite quand j'ai étudié les collections de l'Expédition Charcot.

Les échantillons de la *Scotia*, conservés dans l'alcool, montrent des pédicellaires tout à fait conformes à ceux que MORTENSEN indique. Ce savant a d'ailleurs bien voulu examiner l'un de mes échantillons, de telle sorte que ce point de détermination est maintenant bien établi.

Il faut donc appliquer au *Sterechinus Neumayeri* la description détaillée que j'ai publiée sous le nom d'*Echinus margaritaceus*. Les pédicellaires ayant déjà été décrits par MORTENSEN, je ne vois rien à y ajouter et je me contenterai de donner ici deux dessins, représentant, l'un, une vue latérale du test en partie dépouillé de ses piquants, et l'autre une portion grossie du test. Je rectifierai seulement une erreur d'impression qui m'a fait dire, par une confusion de mots entre les plaques ambulacraires et inter-ambulacraires, que chaque ambulacraire porte un tubercule primaire (*loc. cit.*, p. 31). En réalité les tubercules ambulacraires ne se montrent que de deux en deux ou même de trois en trois plaques ambulacraires.

Trois des échantillons qui m'ont été remis sont d'un brun tirant sur le pourpre ; le quatrième est gris-clair.

### *Sterechinus margaritaceus* (Lamarck).

Voir pour la bibliographie :

DÖDERLEIN, *Echinoideen der deutschen Tiefsee Expedition*, p. 224, pl. xxix. fig. 1, pl. xxxv. fig. 12, pl. xlvii. fig. 9.

1er Décembre 1903, banc de Burdwood, 54° 25′ lat. S., 57° 32′ long. S. ; profondeur 56 brasses. Plusieurs échantillons.

Ainsi que je l'ai dit plus haut, l'espèce que j'ai décrite sous le nom d'*Echinus margaritaceus* dans les Echinodermes de l'Expédition Antarctique française, est le *Sterechinus Neumayeri*.

DÖDERLEIN vient de décrire d'une manière très complète le *St. margaritaceus* qui n'était que très imparfaitement connu par la description et les dessins d'AGASSIZ : c'est donc au mémoire du savant naturaliste allemand qu'il faut se reporter pour tout ce qui concerne cette espèce qu'on peut maintenant facilement reconnaître.

Les échantillons de la *Scotia* sont bien conformes à la description de DÖDERLEIN. Ils forment une très intéressante série, dans laquelle toutes les tailles sont représentées, depuis les plus grands individus, chez lesquels le diamètre du test mesure 50 millim.,

jusqu'aux plus petits qui n'ont que 23 millim. Ils sont en général très aplatis, comme l'indique DÖDERLEIN, mais quelques-uns ont le test conique et la hauteur est alors un peu plus grande que la moitié du diamètre.

Les piquants primaires manquent presque tous. La couleur générale des échantillons est gris-clair.

Le *St. margaritaceus* est très voisin du *St. antarcticus* qui m'a servi de type pour l'établissement du genre *Sterechinus* et il ne saurait être question de placer ces deux espèces dans deux genres différents.

Quant au *St. Neumayeri*, j'ai cru devoir, lorsque je l'ai décrit sous le nom d'*E. margaritaceus*, insister sur certaines difficultés que soulevait son classement dans le genre *Sterechinus* tel que je l'avais établi. Maintenant que les caractères spécifiques des *St. antarcticus*, *margaritaceus* et *Neumayeri* ont été nettement établis, il ressort que le *St. Neumayeri* ne diffère pas suffisamment des deux autres espèces pour qu'il soit logique de le placer dans un autre genre. Je renonce donc à confiner le genre *Sterechinus* dans les limites que je lui avais assignées et que MORTENSEN a élargies et je me range à la manière de voir de ce savant, qui a été également adoptée par DÖDERLEIN.

*Hemiaster elongatus*, nov. sp. (Pl. XVI. fig. 145 à 158.)

1er Février 1904, Baie de la Scotia, Orcades du Sud ; profondeur 6–10 brasses. Quatre échantillons, dont l'un très jeune, et quelques fragments d'un cinquième.

Le plus petit exemplaire n'a que 8 millim. de longueur ; les dimensions respectives des autres sont les suivantes (y compris les piquants) :

| | | | |
|---|---|---|---|
| Longueur, | 45 millim., | 37 millim., | 30 millim. |
| Largeur, | 35 „ | 30 „ | 21 „ |
| Hauteur, | 23 „ | 21 „ | 17 „ |

Vu d'en haut, le pourtour du test est irrégulièrement ovoïde, plus rétréci en arrière qu'en avant ; la plus grande largeur se trouve au niveau de l'appareil apical qui est un peu plus rapproché de l'extrémité antérieure que de l'extrémité postérieure. A l'ambitus, le test n'offre pas une courbe régulière, mais il est plutôt constitué par une série de lignes presque droites ou peu incurvées et réunies par des angles très obtus. En arrière, le corps est aminci. En avant, le pourtour du test n'est pas échancré par le sillon antérieur qui n'atteint pas le bord, mais s'arrête au fasciole, et celui-ci passe à une certaine distance en arrière de ce bord. Vu latéralement, le test offre une courbe régulière qui monte jusqu'à l'appareil apical, puis, en arrière de ce point, on observe une légère gibbosité de l'interradius postérieur. Cette gibbosité, d'ailleurs peu accentuée et visible seulement sur les individus dépouillés de leurs piquants, s'atténue progressivement en arrière en un contour oblique qui se continue avec l'extrémité

postérieure. Celle-ci est étroite et verticale. La face ventrale est peu bombée : elle se relève légèrement en arrière, vers l'extrémité du plastron sternal, en une petite proéminence conique très surbaissée.

L'appareil apical, arrondi, est reporté légèrement en avant. On y remarque trois pores génitaux, deux à gauche et un seul à droite ; celui-ci est placé dans l'interradius postérieur pair. Ces pores sont petits et ovalaires, les deux postérieurs largement séparés par la plaque madréporique. Les sutures des plaques sont absolument indistinctes.

L'ambulacre antérieur impair forme, à la face dorsale du test, un sillon assez large et peu profond, qui va en s'atténuant et disparait au niveau du fasciole sans atteindre le bord antérieur du test. Les zones porifères sont droites et vont en divergeant : chacune d'elles comprend dix-sept à dix-huit paires de pores très fins, dont l'écartement augmente progressivement jusqu'au fasciole. Au delà, les pores sont très peu distincts et beaucoup plus écartés. Les ambulacres latéraux antérieurs et postérieurs ne sont pas très profonds et ils ont à peu près la même longueur : les antérieurs sont très fortement divergents et forment ensemble un angle très obtus, tandis que les postérieurs sont beaucoup plus rapprochés et ne sont séparés que par la gibbosité interradiale postérieure. Dans l'exemplaire représenté fig. 150, je compte dix-sept paires de pores dans les ambulacres antérieurs et dix-huit dans les postérieurs. La partie du test comprise entre chaque ambulacre latéral antérieur et l'ambulacre impair est assez saillante ; entre les deux ambulacres latéraux de chaque côté, le test est moins saillant.

La face ventrale est un peu convexe. L'ambulacre antérieur est peu distinct et il offre vers le bord du test, des tubes ambulacraires identiques à ceux des régions voisines. Les ambulacres antérieurs latéraux sont placés presque sur le prolongement l'un de l'autre et les pores, peu nombreux, forment des lignes convergentes. Les ambulacres latéraux postérieurs sont très larges, nus, et ils n'offrent de tubercules primaires que vers le bord du test. L'interradius postérieur est triangulaire, allongé, avec une très légère proéminence postérieure.

Le péristome se trouve situé à peu près à égale distance entre le milieu de la face ventrale et le bord antérieur du test : il est enfoncé, en forme de croissant et étroit. Le labre est grand et large ; il s'étend en arrière jusqu'au niveau du milieu de la deuxième plaque ambulacraire ; son bord antérieur forme une saillie très marquée, en forme de bec obtus qui cache une partie du péristome.

La face postérieure est verticale et étroite. Le périprocte est petit, une fois et demi au moins plus long que large, acuminé en haut et en bas et placé à fleur du test.

Le fasciole péripétale est nettement plus long que large et son contour est un peu plus sinueux que chez l'*H. cavernosus*. Dans son ensemble, il est ovoïde, avec un léger élargissement au niveau des ambulacres antérieurs latéraux. En avant, son trajet est à peu près rectiligne et il passe à 3 millim. environ du bord antérieur du test ; en arrière, il est plus éloigné du bord du test dont il se trouve séparé par un espace de 8 à 9 millim.

La bande formée par ce fasciole est épaisse. Les clavules sont fines, allongées, élargies vers l'extrémité dont le bord libre se prolonge en pointes inégales.

Les tubercules primaires sont petits, inégaux, perforés et crénelés. Ils sont plus petits et serrés sur la face dorsale ainsi qu'à l'extrémité postérieure, plus gros et plus espacés au contraire sur la face ventrale. Quant aux avenues ambulacraires ventrales, elles n'offrent que des tubercules miliaires.

Les piquants sont assez longs, fins et très serrés. Sur la face dorsale, ils sont à peu près droits, parfois légèrement arqués, un peu élargis à l'extrémité. Ils deviennent un peu plus longs sur la face ventrale et les piquants marginaux de l'interradius postérieur, ainsi qu'un certain nombre des autres piquants interradiaux, sont nettement spatulés. A l'extrémité postérieure du corps, sur la face ventrale, les piquants s'allongent de chaque côté et forment ainsi deux touffes symétriques très marquées, qui donnent à la face ventrale de l'*H. elongatus* une certaine ressemblance avec une *Maretia planulata*. Les piquants qui entourent le périprocte sont aussi plus longs et ils se rapprochent, comme les précédents, par leurs extrémités pour former une petite touffe médiane.

Aucun des exemplaires ne présente la moindre trace de couvée : d'ailleurs les pétales de la face dorsale sont très étroits, ainsi que cela arrive chez le mâle dans le genre *Hemiaster*.

Les pédicellaires sont de quatre sortes.

Il y a d'abord de gros pédicellaires globifères, à tête robuste, allongée et épaisse (fig. 154). La tige calcaire du pédoncule s'étend jusqu'à la base des valves et elle offre, à une certaine distance de son extrémité, un épaississement fusiforme et peu marqué. La partie basilaire des valves est triangulaire, avec de petites perforations serrées, et elle est à peu près aussi longue ou légèrement plus longue que la lame. Celle-ci a la forme d'une goutière ouverte dans sa moitié distale et fermée dans la région proximale par des travées très courtes. Il y a deux crochets terminaux forts et extrêmement allongés. La tête du pédicellaire et l'extrémité distale du pédoncule à partir du renflement sont entourées d'un tissu conjonctif épais et fortement coloré en brun, le tout formant un épaississement ovoïde dont la longueur dépasse 1 millim.

Les pédicellaires de la deuxième sorte sont des pédicellaires rostrés, avec des valves minces et d'assez grosses perforations (fig. 155). La partie basilaire est triangulaire et courte et la lame est presque deux fois plus longue : elle est d'abord très mince, puis elle s'élargit dans son dernier tiers et porte, sur son bord interne qui est droit, une rangée de petites denticulations. Ces pédicellaires ressemblent à ceux que Döderlein a représentés chez l'*H. cavernosus* (*Echinoideen der deutschen Tiefsee Expedition*, pl. l. fig. 6, *u*), mais l'extrémité est plus élargie chez l'*H. elongatus* et ils sont plus grands. Ces pédicellaires sont de dimensions variables et il y en a de grands et de petits ; les premiers mesurent 0·8 millim. de longueur et les petits n'ont que 0·5 millim.

Les pédicellaires tridactyles (fig. 156 et 157), plus rares que les précédents, ont les valves plus élargies et ils rappellent les pédicellaires de l'*H. cavernosus* représentés par Döderlein (*loc. cit.*, pl. l. fig. 7, *d–g*) ; ils n'ont que 0·4 millim. de longueur.

Enfin la quatrième forme comprend des pédicellaires trifoliés, petits, à valves convexes, courtes et larges, finement denticulées sur les bords (fig. 158).

Les spicules des tubes ambulacraires, très petits, sont de forme irrégulière : ils se présentent ordinairement comme de petits bâtonnets plus ou moins recourbés, portant sur leurs bords quelques pointes allongées ; parfois ils sont droits, bifurqués ou non à l'une des extrémités, avec ou sans pointes latérales.

La couleur des échantillons dans l'alcool est gris-foncé.

*Rapports et Différences.*—L'*H. elongatus* se distingue nettement des autres espèces du genre, et notamment de l'*H. cavernosus*, par sa forme beaucoup plus allongée et nettement ovoïde, par l'ambulacre antérieur étroit et moins enfoncé, par la forme et le contour du fasciole, par les touffes de piquants que présente l'extrémité postérieure du corps et par une forme un peu différente des pédicellaires.

### *Hemiaster cavernosus* (Philippi).

Voir pour la bibliographie :

DÖDERLEIN, *Echinoideen der deutschen Tiefsee Expedition*, p. 248.

Dans le bocal renfermant les *Hemiaster elongatus* que je viens de décrire, se trouvait un fragment de face dorsale d'un *Hemiaster* qui devait être de grande taille et dont les pétales offrent la forme caractéristique du sexe femelle dans le genre *Hemiaster*. Ce fragment est presque complètement dépourvu de piquants et je n'ai pu y découvrir de pédicellaires. Il me parait évident qu'il appartient à un *H. cavernosus* : les pétales sont inégaux et les postérieurs sont plus petits que les antérieurs, ainsi qu'on l'observe dans la forme *Philippii*.

### *Delopatagus*, nov. gen.

Ce genre appartient aux Spatangidés dépourvus de fascioles (Adètes) et il peut être placé à côté du genre *Genicopatagus*. Il est particulièrement caractérisé par son pôle apical reporté très en arrière et par les légères dépressions que forment, à la face dorsale du test, les ambulacres latéraux antérieurs et postérieurs : ceux-ci figurent ainsi des pétales, courts et très peu profonds, mais cependant bien reconnaissables. Le test est hémisphérique : la face dorsale est fortement bombée et la face ventrale tout à fait plane. Le péristome est bilabié, peu éloigné du centre de la face ventrale. Le périprocte est situé sur la face postérieure du corps. Les orifices génitaux sont au nombre de trois.

Malheureusement la face ventrale est très fortement endommagée en arrière du péristome et ses caractères ne peuvent pas être indiqués.

*Delopatagus Brucei*, nov. sp. (Pl. XV. fig. 130 à 135.)

10 Mars 1903, 66° 40′ lat. S., 40° 35′ long. W. ; profondeur 2425 brasses. Un seul échantillon.

La face ventrale est incomplète et la partie située en arrière du péristome est réduite en morceaux ; le reste du test est bien conservé.

Les dimensions sont les suivantes :

Longueur, 41 millim.
Largeur, 36 „
Hauteur au niveau de l'appareil apical, 24 millim.

Vu d'en haut, le contour du test est régulièrement ovoïde, presque circulaire ; l'apex est beaucoup plus rapproché du bord postérieur que du bord antérieur et se trouve à 22 millim. en avant de ce bord. La face ventrale est tout à fait aplatie. La face dorsale est convexe : elle forme une courbe régulière, qui descend de l'apex au bord antérieur, lequel est aminci ; en arrière de l'apex, se montre une légère gibbosité qui correspond à l'interradius postérieur et passe insensiblement à la face postérieure du test ; cette face est tronquée et presque verticale ; elle se réunit à la face ventrale en formant un angle arrondi peu accentué. Le péristome est presque central et son bord antérieur est situé à 14 millim. du bord antérieur du test. Le périprocte se trouve placé sur la face postérieure du test : il est ovoïde, élargi verticalement et rapproché de la face dorsale ; son bord inférieur se trouve à 13 millim. du bord inférieur du test.

L'appareil apical est compact, mais je ne puis distinguer les contours des plaques. Les pores génitaux, au nombre de trois, sont gros et arrondis : c'est le pore antérieur droit qui manque. La plaque madréporique occupe la plaque génitale antérieure droite et elle s'avance en arrière en formant un triangle à sommet postérieur arrondi. Je ne distingue pas les plaques ocellaires.

Les deux paires d'ambulacres latéraux de la face dorsale du test sont légèrement pétaloïdes. Les pétales antérieurs forment ensemble un angle obtus et leur longueur atteint un centimètre environ. Ils présentent chacun dix pores bigéminés et les plaques qui les forment sont quadrangulaires, plus larges que longues. Au delà de la région pétaloïde, les plaques ambulacraires deviennent plus larges et elles offrent encore des pores bigéminés sur deux ou trois plaques ; ensuite, elles deviennent très grandes, polygonales et les pores disparaissent. Les limites de ces plaques apparaissent d'ailleurs très difficilement. Dans la région pétaloïde et sur les plaques suivantes qui ont des pores bigéminés, on ne voit sur chaque plaque qu'un ou deux petits tubercules : au delà, les plaques devenues beaucoup plus grandes, offrent chacune un tubercule primaire et quelques tubercules miliaires peu nombreux. Les tubercules primaires sont d'ailleurs de petites dimensions.

Les ambulacres postérieurs offrent les mêmes caractères que les antérieurs, mais ils sont plus courts et leur longueur ne dépasse pas 6 millim. ; ils sont aussi un peu moins

profonds et ils forment ensemble un angle un peu moins obtus. La région pétaloïde présente huit paires de pores bigéminés ; au delà, on peut encore voir une ou deux paires de pores, puis les plaques deviennent beaucoup plus grandes et elles offrent, comme sur les ambulacres antérieurs, chacune un tubercule primaire et quelques tubercules miliaires.

L'ambulacre antérieur est à fleur du test ; il est formé de plaques hexagonales allongées, plus longues que larges, dont les contours sont à peine marqués. Les deux ou trois premières seulement portent deux petits pores bigéminés rudimentaires.

Les plaques interambulacraires sont très grandes, polygonales et larges, mais leurs limites sont presque invisibles ; chacune d'elles porte un ou deux tubercules primaires et quelques tubercules miliaires. D'une manière générale, les tubercules primaires de la face dorsale, aussi bien dans les régions ambulacraires que dans les régions interambulacraires, sont très espacés.

Sur la face ventrale, les tubercules primaires sont plus serrés. Autant que j'en puis juger par les fragments qui sont conservés, les avenues ambulacraires devaient être larges et l'interradius postérieur étroit. Le péristome est élargi et enfoncé : il est constitué par de grandes plaques, à contours peu distincts, sur lesquelles on remarque quelques pédicellaires ; la lèvre postérieure est très saillante. Les tubes ambulacraires qui avoisinent le péristome sont très développés et l'on en trouve trois ou quatre de chaque côté, sur l'ambulacre antérieur et sur les ambulacres latéraux.

Le périprocte est situé dans la partie supérieure de la face postérieure du test. Il est ovoïde, aminci et pointu aux deux extrémités ; il est formé de plaques assez grandes, polygonales, portant des pédicellaires et des piquants. Les tubercules primaires qui se trouvent vers son pourtour portent des piquants particulièrement allongés, couchés sur le périprocte et le recouvrant. L'anus est central.

Les piquants primaires, très espacés sur la face dorsale, sont fins et courts ; ils sont un peu plus longs et plus forts sur la face ventrale.

Les pédicellaires, qui sont assez abondants sur la face ventrale et autour du péristome et se retrouvent aussi sur le périprocte, sont de deux sortes : rostrés et tridactyles. Les premiers, plus nombreux, ont les valves élargies à la base, mais se rétrécissant rapidement et se continuant en une lame étroite et régulièrement recourbée ; ces valves, largement séparées, ne se réunissent l'une à l'autre qu'à leur extrémité qui est amincie. Certains de ces pédicellaires sont ventrus, larges, épais et la partie amincie des valves est plus courte, ainsi que je l'ai représenté Pl. XVI. fig. 134 ; ce sont les moins fréquents ; les autres ont les valves plus longues, plus minces, et ils rappellent la forme que l'on observe chez le *Genicopatagus affinis* par exemple. La longueur de ces pédicellaires est de 0·6 millim. environ.

Les pédicellaires tridactyles sont petits, avec des valves épaisses offrant sur leur bord libre quelques denticulations assez fortes ; elles se réunissent les unes aux autres à leur extrémité par une partie étroite et munie de denticulations beaucoup plus fines. Ils n'ont que 0·3 millim. de longueur (fig. 135).

La couleur générale de l'unique exemplaire recueilli est gris-jaunâtre.

*Urechinus fragilis*, nov. sp. (Pl. XVI. fig. 159 à 162.)

18 Mars 1904, 71° 22′ lat. S., 16° 34′ long. W. ; profondeur 1410 brasses. Un seul échantillon.

Cet exemplaire unique était malheureusement en fort mauvais état : la face dorsale était cassée en plusieurs morceaux et une partie de la face antérieure du test manque. J'ai dû reconstituer en quelque sorte la face dorsale en rapprochant et en collant les morceaux et j'ai pu ainsi obtenir un individu presque complet que j'ai photographié et qui est représenté Pl. XVI. fig. 159–161. La face ventrale est à peu près intacte. Le test est extrêmement mince.

Les dimensions sont les suivantes :

Longueur, 30 millim.
Largeur, 22 „
Hauteur maxima, 12 „ ; cette hauteur est mesurée vers l'extrémité postérieure, en avant de l'anus.

Vu d'en haut, le contour du test est irrégulièrement ovoïde, un peu plus convexe à gauche qu'à droite ; je remarque que l'ambulacre antérieur dorsal ne correspond pas exactement à l'extrémité antérieure et se dirige un peu à gauche. L'extrémité postérieure est pointue.

Vu de côté, le contour de la face dorsale est régulièrement arqué, mais la face ventrale, qui est à peu près plane dans la moitié antérieure, s'abaisse à partir du milieu et forme une saillie assez apparente en avant du périprocte. Le péristome est arrondi : son bord antérieur se trouve à 9 millim. en arrière de l'extrémité antérieure du test. Le périprocte, entièrement situé sur la face ventrale, est ovoïde et allongé longitudinalement : il mesure 4·5 millim. sur 3, et son bord postérieur se trouve à 2 millim. en avant de l'extrémité postérieure. Il n'y a pas la moindre trace de fasciole.

Sur la face dorsale les deux ou trois premières plaques ambulacraires de chaque zone sont très petites, puis ces plaques augmentent rapidement de taille et elles deviennent presqu'aussi grandes que les interambulacraires, mais restent toujours moins larges. Ces dernières sont grandes, larges et peu nombreuses. Chacune d'elles porte, suivant ses dimensions, de un à quatre tubercules primaires et de nombreux tubercules miliaires très serrés. Je n'ai pas pu distinguer les pores ambulacraires. Les renseignements que je puis donner sur l'appareil apical et sur l'origine des zones ambulacraires sont malheureusement très incomplets, à cause de l'état de l'exemplaire. L'ambulacre antérieur impair commence bien avant le milieu de la face dorsale et il ne rejoint pas les ambulacres latéraux

antérieurs ; ceux-ci ne rejoignent pas non plus les ambulacres postérieurs, ainsi que cela arrive chez l'*U. naresianus*. Je ne puis distinguer ni plaque madréporique, ni pores génitaux.

La face ventrale est assez bien conservée, mais les contours des plaques sont mal indiqués. L'interradius postérieur est peu distinct, mais il forme cependant une saillie très marquée en avant du périprocte ; il offre quelques tubercules primaires un peu plus gros que les autres. Les avenues ambulacraires sont assez étroites et garnies de tubercules miliaires avec de rares tubercules primaires. Sur le reste de la face ventrale, les tubercules primaires sont un peu plus gros et plus nombreux que sur la face dorsale, surtout vers les bords.

Le péristome, arrondi, n'offre pas d'indication de lèvre postérieure ; il est couvert de petites plaques polygonales inégales. Le périprocte, relativement très grand, est notablement plus long que large ; il est couvert de petites plaques et l'anus est plus rapproché de son bord postérieur. Il est situé entièrement sur la face ventrale.

L'exemplaire était presque complètement dépourvu de piquants ; ceux qui sont conservés sont courts et fins, d'un gris-violet foncé.

Je ne trouve que deux sortes de pédicellaires. Les plus répandus, dont la longueur varie entre 0·3 et 0·4 millim., sont des pédicellaires tridactyles dont les valves, rétrécies et séparées dans leur région basilaire, se réunissent sur la moitié de leur longueur environ par un bord muni de denticulations très fines (Pl. XVI. fig. 162). Quant aux autres, ce sont des pédicellaires ophicéphales, dont je n'ai trouvé qu'un seul exemplaire dans une préparation montée au baume ; il était entier et se présentait assez mal pour l'étude. Toutefois, il rappelle beaucoup les pédicellaires ophicéphales d'*U. giganteus* et *naresianus* représentés par Mortensen.

*Rapports et Différences.*—Des trois espèces d'*Urechinus* connues, deux ont été rencontrées dans les mers australes. L'*U. fragilis* diffère de l'*U. naresianus* Sladen, que le *Challenger* a dragué entre le 42° et le 50° lat. S., par la position du périprocte qui est entièrement situé sur la face ventrale, tandis qu'il est placé sur la face postérieure du test et d'ailleurs élargi transversalement chez l'*U. naresianus*. L'interradius postérieur forme aussi une saillie moins accusée en avant de l'anus et cette saillie est plus éloignée de l'extrémité postérieure chez l'*U. fragilis* que chez l'*U. naresianus*.

L'*U. Drygalskii* Mortensen, découvert par l'Expédition antarctique Suédoise, a un fasciole sous-anal distinct et le périprocte est placé juste au dessus de l'ambitus.

L'*U. fragilis* rappelle davantage, par son contour, l'*U. giganteus* Agassiz, qui provient du Golfe de Californie ; il s'en distingue également par la position ventrale du périprocte et aussi par la taille beaucoup plus réduite.

### *Pourtalesia carinata*, Agassiz.

AGASSIZ, *Reports of the "Challenger": Echinoidea*, p. 133, pl. xxviii*a*. pl. xxxviii. fig. 30–31 pl. lxi. fig. 49–52, pl. lxii. fig. 24–25, pl. lxiii. fig. 20–23, pl. lxv. fig. 46–52.
LOVEN, *Pourtalesia*, 1884, *passim*, pl. vi. fig. 42–46, pl. vii. fig. 47.
AGASSIZ, "Panamic Deep-sea Echini," *Mem. Mus. Comp. Zool.*, vol. xxxi., 1904, p. 127.

10 Mars 1903, 66° 40′ lat. S., 40° 35′ long. W.; profondeur 2425 brasses. Un échantillon.

21 Mars 1904, 69° 33′ lat. S., 15° 19′ long. W.; profondeur 2620 brasses. Un petit fragment de l'extrémité postérieure du test.

L'échantillon du 10 Mars 1903 est en assez bon état et il est couvert de ses piquants, mais la face ventrale manque sur une certaine étendue ; la coloration est d'un violet foncé. Ses dimensions sont les suivantes :

Longueur, 58 millim.
Largeur maxima, 27 millim.
Hauteur maxima, 22 millim.

Comme cet échantillon était unique, je n'ai pas voulu le dépouiller pour étudier les caractères du test, d'autant plus que celui-ci était rendu très fragile par suite d'une cassure sur la face ventrale. Autant que je puis en juger, il est bien conforme aux descriptions d'AGASSIZ et de LOVEN, du moins en ce qui concerne le test, car les pédicellaires, qu'AGASSIZ a représentés sans les décrire, ne se rapportent pas tous aux dessins de ce savant. Ainsi, je n'ai pas retrouvé les petits pédicellaires du type appelé par lui "clypéastroïde" et qu'il représente pl. xliii. fig. 21-23 ; les autres formes sont plus ou moins conformes aux dessins d'AGASSIZ.

Ceux que j'observe sont de trois sortes.

Les premiers sont des pédicellaires tridactyles dont la tête mesure 0·20 à 0·25 millim. : ils sont représentés par AGASSIZ, pl. xliii. fig. 20. Les valves, larges à la base, se rétrécissent rapidement, puis s'élargissent de nouveau en offrant sur leurs bords une rangée régulière de denticulations triangulaires, serrées et assez fines. Ces pédicellaires sont très abondamment répandus sur toute la surface du test.

Il existe une deuxième forme de pédicellaires tridactyles dont la tête mesure 0·7 à 0·8 millim. de longueur : ils correspondent à ceux qu'AGASSIZ a figurés pl. xlii. fig. 24 et 25 et pl. xlvi. fig. 46 et 47, et qu'il nomme "large-headed, coarsely reticuled hooked pedicellaria." Les valves, très larges à la base, se rétrécissent rapidement, puis conservent une largeur à peu près constante pour s'élargir seulement dans leur partie terminale. Celle-ci porte cinq ou six dents rapprochées, tandis que la valve se termine par un fort crochet, aigu et hyalin. De plus, avant l'origine du crochet, la face externe des valves porte une rangée de dents comme celle qui a été représentée par AGASSIZ (pl. xlii. fig. 24). Les mailles calcaires sont grossières et répondent bien au dessin

d'Agassiz (pl. xlvi. fig. 46). Une membrane pigmentée recouvre les valves et en cache plus ou moins les contours. Ces pédicellaires se montrent surtout au voisinage du péristome et du périprocte.

Les pédicellaires de la troisième sorte ont la tête plus petite et plus ramassée et la longueur de celle-ci est de 0·4 millim. seulement. Les valves, très élargies à la base, se rétrécissent brusquement : elles sont ordinairement infléchies et elles se terminent par deux crochets recourbés ; elles sont entourées d'un tissu compact et fortement pigmenté. Agassiz a représenté ces pédicellaires pl. xlix. fig. 45. Ce sont des pédicellaires globifères ; on les trouve isolés, sur toute la surface du test.

La *Pourtalesia carinata* a été rencontrée par le *Challenger* dans les stations suivantes : 46° 16′ lat. S., 48° 27′ long. E. ; 53° 55′ lat. S., 108° 35′ long. E. ; et 34° 7′ lat. S., 73° 56′ long. W.*

* Pendant l'impression de mon mémoire, j'ai reçu le beau travail de Mortensen sur les Échinides de l'Ingolf, part ii., 1907, et je regrette bien de n'avoir pas pu en profiter pour la rédaction de mes Échinides. Mortensen a étudié la *Pourtalesia carinata* et j'ai remarqué qu'il était arrivé, dans son étude des pédicellaires et ses comparaisons avec les dessins d'Agassiz, à des résultats très voisins des miens. Toutefois, je n'ai pas décrit, ainsi qu'on l'a vu plus haut, les pédicellaires rostrés ; après la réception du mémoire de Mortensen, je les ai cherchés à nouveau et avec le plus grand soin, sans pouvoir les découvrir. Le savant naturaliste danois, auquel j'ai écrit à ce sujet, m'a dit que ces pédicellaires ne se rencontraient effectivement pas sur tous les échantillons, et ceci explique mon insuccès.

En ce qui concerne la structure du test, j'ai dit plus haut que la crainte de détériorer un échantillon unique m'avait empêché de l'examiner de près. Après avoir lu ce que Mortensen écrivait sur la face ventrale, j'ai revu mon exemplaire et je crois pouvoir confirmer ce que mon savant ami a décrit. Malheureusement, l'état de la face ventrale ne m'a pas permis de suivre tous les contours des plaques, surtout dans la région médiane où se trouve un gros trou, dont la présence offre en outre l'inconvénient de diminuer beaucoup la solidité du test.

## SECONDE PARTIE.

### ÉCHINODERMES RECUEILLIS PAR LA "SCOTIA" PENDANT SON VOYAGE DE RETOUR.

Les quelques espèces qu'il me reste à étudier ont été rencontrées par la *Scotia*, au cours de son voyage de retour, au Cap, à Sainte-Hélène, à l'Ascension et aux îles du Cap Vert. J'y ajouterai deux Ophiures, dont l'une est nouvelle, trouvées pendant le voyage d'aller par 18° 24′ lat. S. et 37° 58′ long W., sur le banc d'Abrolhos, à une profondeur de 36 brasses.

Un Échinide provenant de l'Ascension et rapporté par AGASSIZ au *Cidaris tribuloides*, me parait devoir en être distingué et il constitue, soit une espèce, soit une variété différente. Quant aux autres espèces, un certain nombre d'entre elles méritent plus qu'une simple mention, car elles avaient été insuffisament étudiées jusqu'à maintenant et il m'a paru utile de les figurer et de les décrire complètement.

Le nombre total des espèces recueillies s'élève à dix-huit en tout, qui se répartissent en classes de la manière suivante:

#### ASTÉRIES.

*Cribrella ornata* (Perrier). Cap de Bonne Espérance.
*Moiraster magnificus*, J. Bell. Ascension. Profondeur 40 brasses.
*Patiria bellula*, Sladen. Cap.
*Asterina calcarata* (Valentin). Cap.
*Linckia Bouvieri*, Perrier. Sainte-Hélène.
*Chætaster longipes* (Retzius). Ascension.

#### OPHIURES.

*Amphiura murex*, nov. sp. 18° 24′ lat. S., 37° 58′ long. W. Profondeur 36 brasses.
*Amphiura capensis*, Lyman. Cap.
*Ophiopsila maculata* (Verrill). 18° 24′ lat. S., 37° 58′ long. W. Profondeur 36 brasses
*Ophiothrix fragilis*, forme *pentaphyllum*, Lyman. Cap.
*Ophiothrix triglochis*, Müller et Troschel. Cap.

#### ÉCHINIDES.

*Tretocidaris spinosa*, Mortensen. Ascension. Profondeur 49 brasses.
*Cidaris minor*, sp. aut var. nov. Ascension. Profondeur 40 brasses.
*Cidaris tribuloides*, Lamarck. Sainte-Hélène.
*Cœlopleurus floridanus*, Agassiz. Ascension. Profondeur 40 brasses.
*Echinometra subangularis* (Leske). Ascension (40 brasses) et Saint-Vincent (24 brasses).
*Paracentrotus angulosus* (Leske). Cap.
*Pseudoboletia maculata*, Troschel. Ascension. Profondeur 40 brasses.

## ASTÉRIES.

### *Cribrella ornata* (Perrier). (Pl. XII. fig. 105 et 106.)

*Echinaster ornatus*, Perrier, "Pédicellaires et ambulacres," *Ann. Sc. Nat. Zool.* (5), vol. xii., 1869, p. 59.
*Cribrella ornata*, Perrier, "Révision des Stellérides du Muséum," *Arch. Zool. exp.* (1), vol. vi., 1875, p. 112.

Baie de Saldanha (Cap). Trois échantillons.

*R* varie de 30 à 34 millim. et *r* de 9 à 10 millim. Les bras sont plutôt arrondis et coniques, à pointe très obtuse.

J'ai comparé ces exemplaires aux deux types de PERRIER qui se trouvent au Jardin des Plantes et j'ai constaté qu'ils leur étaient absolument conformes ; mais je remarque que les piquants adambulacraires ne sont pas disposés comme l'indique PERRIER, et cela aussi bien sur les échantillons de la *Scotia* que sur ceux du Muséum. Je trouve, en effet, sur chaque plaque adambulacraire, une rangée transversale de quatre gros piquants, cylindriques et à extrémité arrondie, et, en dedans, un très petit piquant caché par les tubes ambulacraires. Parfois il n'y a que trois piquants et ce chiffre s'observe toujours au delà de la deuxième moitié du bras.

La rangée de plaques latéro-ventrales qui fait immédiatement suite aux adambulacraires, offre, en général, deux séries parallèles de piquants courts et obtus, au nombre de trois et parfois de quatre dans chaque rangée. Toutefois, cet ordre régulier n'est pas tout à fait constant, et, de plus, la rangée en question ne correspond pas toujours aux adambulacraires, une plaque latéro-ventrale manquant de distance en distance. En dehors de cette première rangée, on en reconnait une autre plus ou moins distincte. Les plaques de ces deux séries sont très serrées les unes contre les autres et les papules qu'on peut voir entre elles sont peu nombreuses. En dehors de la seconde rangée, les plaques se disposent irrégulièrement en un réseau identique à celui de la face dorsale et les papules deviennent beaucoup plus nombreuses.

L'un des exemplaires du Jardin des Plantes est un peu plus grand que ceux de la *Scotia* : il mesure 40 millim. et les bras sont plus minces ; l'autre exemplaire est plus petit ($R = 30$ millim.), et il rappelle davantage les échantillons de la *Scotia*, mais il est déformé et aplati, de sorte que la comparaison est incertaine.

SLADEN a rapproché de la *Cr. ornata* la *Cr. obesa* qu'il a décrite d'après les échantillons trouvés par le *Challenger* aux îles Falkland (profondeur 12 brasses) et à l'entrée du détroit de Smyth (profondeur 245 brasses). Il est certain que ces deux espèces sont très voisines, et les piquants adambulacraires que j'observe chez la *Cr. ornata* ont bien la disposition que SLADEN a figurée chez la *Cr. obesa*. Toutefois, les exemplaires du Cap n'ont pas ce réseau dorsal à grosses mailles, ni ces rangées régulières

de plaques sur les côtés des bras que SLADEN indique chez la *Cr. obesa*. Mais ces variations sont de peu d'importance et il est possible que les deux espèces doivent être réunies en une seule.

Puisque, d'autre part, on s'accorde à considérer comme synonymes les différentes Cribrelles subantarctiques décrites sous les noms de *Cr. Pagenstecheri*, *Hyadesi*, *Studeri* et *obesa*, il n'y aurait rien d'impossible à ce que la même espèce de Cribrelle s'étendît depuis le Cap de Bonne Espérance jusqu'au Cap Horn, en présentant de nombreuses variations. Cette question ne pourra être résolue que par une comparaison de tous les exemplaires originaux des formes décrites.

### *Moiraster magnificus* (J. Bell). (Pl. XII. fig. 107 à 110.)

*Archaster magnificus*, J. Bell, "Description of a new Species of Archaster from St Helena," *Ann. and Mag. Nat. Hist.* (5), vol. viii., 1881, p. 440.
*Moiraster magnificus*, Sladen, *Reports of the "Challenger" : Asteroidea*, p. 193.

10 Juin 1904, Pointe Pyramid, Ascension ; profondeur 40 brasses. Un seul échantillon.

$R = 62$ millim. sur le plus grand bras, $r = 19$ ; l'un des bras est en voie de régénération.

Le type de cette espèce provient de Sainte-Hélène et il est représenté par un exemplaire unique beaucoup plus grand que l'échantillon de la *Scotia*, les dimensions indiquées par BELL étant : $R = 207$ millim. et $r = 50$ millim. L'échantillon de la *Scotia* est un peu différent du type de BELL et il me parait utile de le décrire et de le figurer, mais les légères différences que j'observe tiennent sans doute au jeune âge de cet individu.

Le disque est très grand ; les bras sont très larges à la base qui mesure 20 millim., et ils vont en diminuant rapidement jusqu'au sommet qui est assez pointu.

La face dorsale du disque et des bras, presque plane, est couverte de paxilles serrées et petites, qui, dans la région centrale du disque, sont confluentes et ne laissent pas reconnaître leurs contours, mais qui sont bien distinctes dans la moitié périphérique du disque et sur les bras. Les plus grandes ont 0·7 à 0·8 millim. de diamètre. Chaque paxille offre un groupe central de trois à cinq granules entourés d'un cercle périphérique à peu près de mêmes dimensions. Sur les bras, les paxilles forment une bande médiane dans laquelle elles sont un peu plus petites et plus rapprochées ; de cette bande partent des rangées très régulières et légèrement obliques, qui atteignent les plaques marginales dorsales. A la base des bras, il y a une dizaine de paxilles dans chacune de ces rangées. L'aire paxillaire des bras est relativement large.

L'anus est invisible. La plaque madréporique est petite et arrondie, tandis que BELL dit qu'elle est grande ; elle offre des sillons divergents à partir du centre. Elle est plus rapprochée du bord que du centre du disque.

Les plaques marginales dorsales sont petites : elles sont beaucoup plus larges que longues et les dernières sont extrêmement petites ; serrées et j'en compte cinquante sur chaque bras. Elles sont séparées par des sillons peu profonds et couvertes de granules arrondis qui sont plus gros dans la partie centrale et deviennent plus petits vers la périphérie. Ces granules ne forment pas de rangées plus distinctes au milieu des plaques que vers les bords.

Les plaques latéro-ventrales forment des séries s'étendant des adambulacraires aux marginales. Les séparations transversales de ces plaques ne sont pas très apparentes en raison des piquants qui les recouvrent, mais les alignements qu'elles forment sont bien réguliers et distincts. Il y a environ huit plaques successives dans la série la plus voisine de la ligne interradiale médiane, puis le nombre des plaques diminue rapidement dans chaque série. On peut suivre ces plaques latérales jusque vers le milieu du bras. Elles offrent un revêtement très serré de petits piquants cylindriques, à extrémité arrondie : habituellement ces petits piquants forment sur la plaque une bordure périphérique entourant un ou deux piquants centraux un peu plus grands, mais surtout plus larges, plus aplatis et obtus à l'extrémité. Cette disposition rappelle ce que l'on observe chez diverses espèces d'*Astrogonium* ; elle est un peu différente de celle que BELL a décrite.

Les plaques marginales ventrales portent aussi de petits piquants sur leur région périphérique, tandis que dans leur région médiane, les piquants s'allongent et surtout s'élargissent en même temps qu'ils s'aplatissent. On peut distinguer en général trois ou quatre de ces gros piquants et parfois cinq dans l'arc interbrachial : tous sont relativement courts et ils ont l'extrémité très obtuse. L'avant-dernier de ces piquants occupe le bord de la plaque et il forme un légère saillie qui est visible de la face dorsale.

Les plaques adambulacraires portent trois rangées successives de piquants. La première comprend une rangée de quatre à cinq piquants subégaux, petits, aplatis, à extrémité arrondie. La deuxième comprend deux ou trois piquants et parfois quatre, dont deux en général se distinguent par leur grande largeur : ils sont aplatis. La troisième rangée, plus irrégulière, est composée de quatre ou cinq piquants, dont un ou deux sont beaucoup plus larges que les autres.

Les dents, très peu proéminentes, portent sur leur bord libre une rangée de piquants qui continuent les piquants adambulacraires internes ; ceux-ci deviennent alors cylindriques et s'allongent, surtout vers l'extrémité de la dent. La surface ventrale des dents offre des piquants courts, élargis à l'extrémité qui est obtuse et disposés en deux ou trois rangées irrégulières, très rapprochées de leurs congénères de l'autre côté.

Les tubes ambulacraires sont allongés, comprimés, coniques et pointus.

*Patiria bellula*, Sladen.

SLADEN, *Reports of the "Challenger" : Asteroidea*, p. 385, pl. lxiii. fig. 1–2, et pl. lxiv. fig. 5–6.

Baie de Saldanha (Cap). Un échantillon tout à fait conforme au type de SLADEN, qui provenait aussi du Cap.

*Asterina calcarata* (Valenciennes).

Voir pour la bibliographie :

MEISSNER, "Die von Plate aus Chile und Feuerland heimgebrachten Seesterne," *Arch. für Nat.*, 1896, p. 97.

8 Mai 1904, Baie False (Cap). Quatre échantillons.

19 Mai 1904, Baie de Saldanha (Cap). Quelques échantillons.

Les dimensions moyennes des échantillons sont les suivantes : $R = 12$ millim. et $r = 10$ millim. Dans quelques individus, $R$ mesure 14 et 15 millim. Tous les exemplaires ont cinq bras, sauf un seul qui en a six.

J'ai comparé ces exemplaires à d'autres qui proviennent de la côte du Chili et qui m'ont été communiqués de différents côtés ; j'ai constaté leur identité complète. L'*A. calcarata* peut donc remonter plus haut vers le Nord qu'on ne le croyait.

*Linckia Bouvieri*, Perrier.

PERRIER, "Révision des Stellérides du Muséum," *Arch. Zool. exp.*, 1° série, vol. v., p. 150.

2 Juin 1904, Sainte-Hélène. Un échantillon de petite taille : $R = 35$ millim. et $r = 4$ millim.

Malgré ces petites dimensions, l'exemplaire est très bien caractérisé. Je figure cette espèce, d'après des échantillons adultes recueillis par S.A.S. le PRINCE DE MONACO, dans un mémoire actuellement sous presse.

L'espèce n'avait pas encore été signalée dans l'Atlantique S.

*Chætaster longipes* (Retzius).

Voir pour la bibliographie :

LUDWIG, *Fauna und Flora des Golfes von Neapel : Asteroidea*, 1897, p. 134.

10 Juin 1904, Pointe Pyramid, Ascension. Profondeur 40 brasses. Deux échantillons, dans lesquels $R = 42$ millim. et $r = 5$ millim.

Malgré leur petite taille, ces exemplaires sont très reconnaissables ; ils sont identiques aux individus de la Méditerranée.

L'espèce n'avait pas encore été observée dans l'Atlantique S. et sa découverte à l'Ascension est très intéressante.

## OPHIURES.

*Amphiura murex*, nov. sp. (Pl. XIII. fig. 115 et 116.)

20 Décembre 1902, 18° 24′ lat. S., 37° 58′ long. W. Profondeur 36 brasses. Deux échantillons.

Diamètre du disque, 2·5 millim. Les bras sont très fins, grêles et allongés, assez fortement contournés, ce qui empêche de les mesurer, mais ils ont au moins 25 millim. de longueur.

Le disque est arrondi. La face dorsale est couverte de plaques plutôt grandes, subégales, peu ou pas imbriquées. Dans l'un des exemplaires, on ne reconnait pas de plaques primaires, tandis que dans l'autre ces plaques sont bien distinctes. A la périphérie du disque, on trouve une bordure de plaques plus grandes et plus larges. Les boucliers radiaux sont assez grands, contigus sur presque toute leur longueur et séparés en dedans seulement par une petite plaque triangulaire ; leur bord interradial est fortement convexe et leur longueur est un peu supérieure au tiers du rayon du disque.

La face ventrale du disque n'offre pas de plaques distinctes, mais elle est couverte de petits granules très fins et très serrés, pointus et coniques. Les fentes génitales sont très larges ; je ne distingue pas de plaques sur leurs bords.

Les boucliers buccaux, de moyenne grosseur, sont triangulaires avec un angle proximal aigu et un bord distal fortement convexe ; ils sont aussi larges que longs ou un peu plus longs que larges. Les plaques adorales sont assez fortes, élargies en dehors, rétrécies et contiguës en dedans. Les plaques orales sont petites. Les papilles buccales sont disposées comme dans les espèces de la section *Amphipholis* : la papille externe est grande et rectangulaire et les deux autres sont courtes, épaisses, subégales.

Les plaques brachiales dorsales sont pentagonales, aussi larges que longues, avec un angle proximal obtus, et des bords latéraux droits se réunissant par des angles arrondis au côté distal, qui est presque droit ou légèrement arrondi. Elles sont séparées dès la base du bras.

La première plaque ventrale est extrêmement petite, pentagonale, avec un angle proximal dont les deux côtés sont contigus au bord distal de la papille buccale externe. Les plaques suivantes, de moyenne grosseur, sont pentagonales, aussi larges que longues, avec un angle proximal très obtus, et un côté distal légèrement échancré en son milieu. Elles sont largement séparées. Les plaques latérales portent trois piquants cylindriques, subégaux et à extrémité obtuse.

Les pores tentaculaires sont munis de deux écailles très petites.

*Rapports et Différences.*—L'*A. murex* appartient à la section *Amphipholis*. Elle est extrêmement voisine de l'*A. granulata* Lütken et Mortensen, et j'ai même hésité à l'en séparer; cependant certaines différences ne permettent pas de les confondre: les plaques brachiales dorsales de l'*A. murex* ont une forme différente, de plus, elles sont aussi larges que longues et séparées; les plaques brachiales ventrales, tout en rappelant par leur forme celles de l'*A. granulata*, sont aussi larges que longues; enfin les piquants brachiaux ne sont pas pointus. Ces différences tiennent peut-être à l'âge, mes exemplaires étant de très petite taille; néanmoins, il ne me parait pas possible de les réunir à l'*A. granulata*. Je ne parle pas ici des plaques primaires, ce caractère ne pouvant être invoqué, puisque l'un de mes échantillons les montre, tandis qu'elles ne sont pas distinctes dans l'autre.

### *Amphiura capensis*, Lyman.

Voir pour la bibliographie :

LYMAN, *Reports of the "Challenger": Ophiuroidea*, p. 129.

21 Mai 1904, Baie de Saldanha (Cap); profondeur 25 brasses. Quelques échantillons.

10 Juin 1904, Ascension. Un seul échantillon.

L'écaille tentaculaire n'est pas tout à fait aussi grande que sur les dessins de LYMAN. Les plaques primaires sont en général bien distinctes, ainsi que l'indique LYMAN, mais il est à remarquer qu'il ne les a pas figurées sur son dessin. Je remarque également que les papilles buccales sont représentées d'une manière plus correcte sur le dessin des *Mem. Mus. Comp. Zool.* que sur celui de la publication du *Challenger*.

J'observe en général sept piquants à la base des bras.

### *Ophiopsila maculata* (Verrill).

*Amphipsila maculata*, Verrill, "Report of the Ophiurids collected by the Bahama Expedition," *Bull. from the Lab. Nat. Hist., State University, Iowa*, vol. v., 1899, p. 55, pl. iii. figs. 4–4*a*.

20 Décembre 1902, 18° 2′ lat. S., 37° 58′ long. W.; profondeur 36 brasses. Un seul échantillon.

Diamètre du disque, 3·5 millim.

Il n'y a que cinq piquants brachiaux; les deux inférieurs sont plus longs que les autres, mais c'est surtout le piquant ventral qui est le plus long; il est, de plus, légèrement recourbé, caractère que VERRILL n'indique pas.

Il existe des taches brunes allongées sur les côtés de la face dorsale des bras et sur le milieu des plaques brachiales dorsales. On remarque également une double trainée de taches brunes sur la face ventrale des bras et un point brun sur chaque bouclier buccal. Le disque est gris, avec de grandes taches jaunes irrégulières.

Je ne crois pas devoir séparer cette Ophiure de l'*A. maculata*, quoique le type de VERRILL ait un plus grand nombre de piquants brachiaux ; cette différence tient sans doute à ce que mon exemplaire est très jeune, car celui de VERRILL avait 6 millim. de diamètre.

Ce type provenait de La Havane et avait été recueilli à une profondeur de 200 brasses. Cette station n'est pas très éloignée de celle où la *Scotia* a retrouvé l'espèce, mais elle appartient à l'Atlantique boréal.

### *Ophiothrix fragilis* (Abildgard).

Voir : KOEHLER, "Révision des Ophiures du Muséum," *Bulletin Scientifique*, 1907, p. 332.

Baie de Saldanha (Cap). Trois échantillons.

Ces exemplaires appartiennent à la forme *pentaphyllum* telle que je l'ai définie ; ils sont absolument conformes à certains individus que je possède dans ma collection et qui proviennent du Pas-de-Calais.

Ce n'est pas sans une extrême surprise que j'ai rencontrée cette *Ophiothrix* dans les collections de la *Scotia*, et s'il n'y a pas une erreur d'étiquettage, on voit que cette forme descend beaucoup plus vers le Sud qu'on ne pouvait le supposer.

### *Ophiothrix triglochis*, Lütken.

Voir pour la bibliographie :

KOEHLER, "Ophiures nouvelles ou peu connues," *Mém. Soc. Zool. France*, 1904, p. 114, fig. 41 à 45.

8 Mai 1904, Baie False. Un seul échantillon.

Diamètre du disque, 8 millim.

Les bâtonnets de la face dorsale du disque sont plus grands que d'habitude et constituent des piquants terminés par trois ou quatre spinules. Les piquants brachiaux sont aussi munis de denticulations plus fortes que d'ordinaire.

## ÉCHINIDES.

### *Tretocidaris spinosa*, Mortensen. (Pl XVI. fig. 163 et 164.)

*Tretocidaris spinosa*, Mortensen, *The Danish Ingolf Expedition: Echinoidea*, 1903, p. 17, pl. x. fig. 10, 11 et 16.

10 Juin 1904, Pointe Pyramid, Ascension; profondeur 40 brasses. Quatre échantillons.

Dans le plus grand exemplaire que j'ai représenté Pl. XVI. fig. 163 et 164, le diamètre du test, sans les piquants, est de 35 millim. environ et la hauteur de 22. Dans deux autres, ce diamètre mesure respectivement 30 et 37 millim. Le dernier individu, très petit, a seulement 7 millim., mais il est déjà bien reconnaissable et il offre quelques pédicellaires caractéristiques.

Le nom de *Tretocidaris spinosa* a été appliqué par MORTENSEN à un Échinide du British Museum, provenant de Sainte-Hélène, sans autre indication, et qui diffère du *T. Bartleti* par la forme des pédicellaires globifères. Voici le renseignement que MORTENSEN donne sur le test et les piquants:

"Les piquants offrent des sillons rapprochés et des denticulations plutôt fines: ils sont élargis à la pointe et leur longueur est égale au diamètre du test. Les piquants actinaux sont délicats, lisses, non élargis à l'extrémité. Les petits piquants ont une couleur rouge. Une ligne médiane nue s'étend le long de chaque aire interambulacraire, mais elle est peu apparente. Il y a neuf tubercules primaires dans chaque aire interambulacraire, de telle sorte que les grands piquants sont plus nombreux que d'habitude, ce qui donne à l'Oursin un facies très caractéristique. Les tubercules des aires ambulacraires sont disposés comme chez le *T. annulata*."

Dans une lettre particulière, M. MORTENSEN a bien voulu me donner les renseignements complémentaires suivants, retrouvés dans ses notes, sur le *T. spinosa* du British Museum:

"Les plaques ocellaires rejoignent les plaques du périprocte et séparent ainsi les plaques génitales. Chaque plaque interambulacraire correspond à douze plaques ambulacraires dans le milieu de chaque série. Il existe des piquants secondaires entre tous les radioles, de telle sorte que les aréoles ne sont pas confluentes. Les tubercules ne sont pas crénelés."

Les exemplaires de la *Scotia* présentent quelques légères différences avec le type de MORTENSEN, différences qui portent surtout sur la forme des piquants et le nombre des tubercules primaires des aires interambulacraires. Mais M. MORTENSEN, qui a bien voulu

revoir mes échantillons, a confirmé ma détermination et il estime que ces différences, notamment celle qui porte sur le nombre des tubercules primaires, tiennent au jeune âge de ces échantillons, car, m'a-t-il écrit, le type du British Museum est beaucoup plus grand.

Voici les caractères que j'observe sur le plus grand individu :

Les plaques interambulacraires sont au nombre de sept, dont les dimensions augmentent progressivement depuis la première ventrale jusqu'à la cinquième, la sixième étant à peu près aussi grande que la cinquième. Dans l'une des deux séries, on remarque entre la dernière plaque interambulacraire et le cercle des plaques génitales et ocellaires, une très petite plaque triangulaire qui représente une huitième plaque. Les tubercules, perforés, ne sont pas crénelés. Les aires scrobiculaires, d'abord elliptiques, tendent à devenir circulaires au dessus de l'ambitus. Tout le reste de la surface des plaques est couvert de tubercules secondaires et miliaires très serrés. Sur les plus grandes plaques, on distingue un premier cercle assez régulier de tubercules secondaires entourant la fossette scrobiculaire, puis, en dehors, viennent deux cercles plus distincts de tubercules secondaires séparés par des tubercules miliaires. Les deux premières fossettes sont confluentes. Un seul rang de granules sépare la deuxième de la troisième et la troisième de la quatrième ; enfin les autres sont séparés par un double rang et même par deux doubles rangs de granules. Les tubercules ne vont pas jusqu'au bord sutural et la ligne médiane en zig-zag de chaque zone interambulacraire est nue.

A l'ambitus, une plaque interambulacraire correspond à douze plaques ambulacraires. Les zones porifères sont assez larges et les pores de chaque paire sont éloignés l'un de l'autre ; chaque paire est séparée des suivantes par un rebord légèrement saillant. Chaque plaque ambulacraire porte un tubercule secondaire, immédiatement en dedans de la zone porifère, et ces tubercules forment une rangée très régulière. En dedans, on observe sur chaque plaque, soit un seul tubercule, soit deux plus petits.

Les plaques génitales sont très grandes, quadrangulaires, à peu près aussi longues que larges ou un peu plus larges que longues, munies de petits tubercules assez serrés. Les pores génitaux, petits, sont situés vers le tiers externe de la plaque. La plaque madréporique ne se distingue pas des autres par sa taille et les pores sont à peine distincts. Les plaques ocellaires sont petites, triangulaires, avec le bord externe échancré ; elles sont situées dans les intervalles des plaques génitales, et, en général, contiguës au périprocte. Sur l'exemplaire que j'ai sous les yeux, trois des plaques ont l'angle proximal tronqué et contigu à une plaque anale, la quatrième a le sommet pointu mais touche encore à une plaque anale ; enfin la dernière est éloignée du périprocte. Celui-ci est occupé par des plaques peu nombreuses et irrégulières, relativement grandes en dehors et plus petites vers le centre.

La plupart des piquants primaires manquent ou sont cassés dans l'individu que je décris. Dans les autres, les piquants se montrent, comme le dit Mortensen, très

nettement canaliculés et les crêtes qui séparent les sillons sont fortement rugueuses, mais ils sont à peine élargis à l'extrémité. Ils peuvent être plus grands que le diamètre du test : ainsi, dans l'individu ayant 30 millim. de diamètre, le plus long piquant atteint 38 millim. de longueur, et dans l'exemplaire de 27 millim. de diamètre, le plus long piquant a 40 millim. Ces piquants offrent de larges bandes alternativement roses et brunes.

Les sillons s'effacent sur les piquants de la face ventrale qui finissent par être tout à fait lisses, en même temps qu'ils s'aplatissent.

Les piquants secondaires sont serrés, aplatis et ils offrent des sillons très fins ; ils laissent à nu le milieu des zones interambulacraires. Ils sont d'une couleur rouge-brun très vive, avec la base verdâtre.

Les caractères des pédicellaires ont été très bien indiqués par MORTENSEN, à la description et aux dessins duquel je n'ai rien à ajouter.

### *Cidaris minor*, sp. aut var. nov. (Pl. XV. fig. 136 à 138.)

*Cidaris tribuloides* juv., Agassiz, *Reports of the "Challenger" : Echinoidea*, p. 36, pl. i., fig. 3, 5 et 6.

10 Juin 1904, Pointe Pyramid, Ascension ; profondeur 40 brasses. Un seul échantillon.

L'exemplaire est de très petite taille et le diamètre du test ne dépasse pas 11 millim.

Dans le *Report* sur les Échinides du *Challenger*, AGASSIZ rapporte au *Cidaris tribuloides* quelques exemplaires d'un Échinide trouvés à Bahia et à Fernando Noronha, par 7 à 20 brasses de profondeur, et qui sont tous de petite taille, le diamètre du plus grand ne dépassant pas 17 millim. Au premier abord, dit AGASSIZ, ces Oursins offrent une certaine ressemblance avec de jeunes *Phyllacanthus verticillata*, mais, en somme, ils ont bien les caractères des *Cidaris tribuloides* et les différences que l'on observe avec les adultes ne sont pas plus marquées que celles que l'on peut trouver chez les *Goniocidaris tubaria*. D'ailleurs ces jeunes individus ont été rencontrés dans des localités où vit précisément le *Cidaris tribuloides*. AGASSIZ a donc considéré ces Cidaridés comme appartenant à cette dernière espèce. Il les a représentés pl. i. fig. 3, 5 et 6 de son mémoire.

MORTENSEN, qui a vu ces Échinides au British Museum, est d'avis de les séparer du *Cidaris tribuloides* pour en faire une espèce nouvelle. Or, un simple coup d'œil jeté sur les dessins d'AGASSIZ montre que l'exemplaire recueilli par la *Scotia* appartient à la même forme. Peut-être s'agit-il simplement d'une simple variété du *Cidaris tribuloides*. Je propose de lui donner le nom de *Cidaris minor*, sans pouvoir décider formellement si c'est une espèce distincte du *C. tribuloides* ou une simple variété de ce dernier.

Aux indications fournies par AGASSIZ, j'ajouterai quelques remarques, qui, jointes aux dessins que je donne, permettront de reconnaître ce *Cidaris*. Malheureusement l'échantillon unique que j'ai entre les mains ne me permet pas de donner une description complète de cette intéressante forme, car j'ai tenu à le laisser intact et je dois me borner à décrire l'animal couvert de ses piquants.

Les zones interambulacraires portent chacune cinq piquants primaires dont la longueur augmente du premier ventral au dernier dorsal, qui atteint 8 à 9 millim. Ces piquants sont garnis de dents coniques disposées en séries longitudinales ; en certains points, les dents deviennent beaucoup plus fortes et elles se rapprochent pour constituer des sortes de verticilles. Sur les plus grands piquants de mon exemplaire, le nombre de ces verticilles ne dépasse pas le chiffre deux ; mais sur les individus plus grands, leur nombre peut être plus élevé, puisqu'AGASSIZ en indique trois ou quatre. Enfin l'extrémité du piquant est élargie et porte huit ou dix dents. Ces caractères sont surtout marqués sur les piquants dorsaux et ils s'effacent progressivement sur les autres piquants ; les piquants ventraux offrent simplement des rangées de fines denticulations. Ces piquants peuvent présenter des parties alternativement claires et foncées et les parties claires correspondent aux verticilles.

Les piquants secondaires, très serrés, sont aplatis et finement sillonnés. Dans les zones ambulacraires, ils sont rouges avec une ou deux bandes blanches plus ou moins apparentes, tandis que dans les interradius, ils sont blancs avec une ou deux bandes rouges.

Les plaques génitales sont légèrement trapézoïdales, à peu près aussi longues que larges. Le pore génital se trouve un peu en dehors du milieu de la plaque. Les plaques ocellaires sont triangulaires, plus larges que longues, avec l'angle proximal légèrement tronqué et contigu au périprocte. Celui-ci est couvert de plaques assez grandes qui portent toutes de petits piquants coniques et dressés.

Je n'ai trouvé qu'une seule sorte de pédicellaires, très rares et très petits. Ce sont des pédicellaires globifères qui ressemblent aux petits pédicellaires globifères figurés par MORTENSEN chez le *Cidaris affinis* et par AGASSIZ et LYMAN CLARK chez le *C. tribuloides*. L'orifice terminal est grand et la dent terminale est bien développée ; les bords sont garnis de dents serrées, fines et pointues (fig. 138).

Si le *C. minor* est une espèce distincte, il est vraisemblable qu'elle reste de très petite taille ; jusqu'à présent, les plus gros échantillons connus ne dépassent pas 17 millim. de diamètre. Il est à souhaiter que d'autres exemplaires soient rencontrés afin qu'on puisse étudier d'une manière plus complète les caractères du test, et décider d'abord, par l'examen des organes génitaux, si les individus de la taille de celui qu'a recueilli la *Scotia* sont adultes, et ensuite, par une étude plus complète des caractères extérieurs, s'ils représentent une espèce distincte ou s'ils ne forment qu'une variété du *C. tribuloides*.

### *Cidaris tribuloides*, Lamarck.

Voir pour la bibliographie :

KOEHLER, *Résultats scientifiques des campagnes du Prince de Monaco*, fasc. xii., 1888, "Échinides et Ophiures," p. 8.

Et ajouter :

LYMAN CLARK, "The Echinoids and Asteroids of Jamaica," *Johns Hopkins Univ. Circ.*, vol. xviii., 1898, p. 4 ; "The Echinoderms of Porto Rico," *Bull. U.S. Fish Comm. for* 1900, p. 252 ; "Bermudan Echinoderms," *Proc. Boston Soc.*, vol. xxix., 1901, p. 344.

AGASSIZ et LYMAN CLARK, "Hawaian and other Pacific Echini," *Mem. Mus. Comp. Zool.*, vol. xxiv., 1906, p. 3, pl. ii. fig. 1–4.

2 Juin 1904, Baie de James, Sainte-Hélène. Deux échantillons.

### ? *Cœlopleurus floridanus*, Agassiz.

Voir pour la bibliographie :

DÖDERLEIN, *Echinoideen der deutschen Tiefsee Expedition*, 1906. p. 181, pl. xlv. fig. 2.

10 Juin 1904, Pointe Pyramid, Ascension ; profondeur 40 brasses. Un seul échantillon.

Cet individu a le test à peu près complètement dénudé et il est d'ailleurs de très petite taille, son diamètre ne dépassant pas 9 millim. Quelques pédicellaires ophicéphales sont conservés et ils sont identiques à ceux que DÖDERLEIN a représentés chez cette espèce. Les zones ambulacraires sont d'un rose vif.

La détermination de cet individu très jeune et incomplet reste forcément douteuse et peut-être appartient-il à une espèce nouvelle : il se rapproche en tous cas beaucoup du *C. floridanus*, qui n'était connu, jusqu'à présent, que dans la région équatoriale de l'Atlantique boréal.

### *Echinometra subangularis* (Leske)
### = *Ech. lucunter* (Linné).

1er Décembre 1902, Porto Grande, Saint-Vincent, îles du Cap Vert ; profondeur 24 brasses. Deux petits échantillons.

2 Juin 1904, Baie de James, Sainte-Hélène. Deux grands échantillons.

Ainsi que le rappelle MORTENSEN dans son travail sur les Échinides de l'*Ingolf*, LOVEN a établi que cette espèce était l'*E. lucunter* de LINNÉ : c'est donc ce nom qui devrait lui être donné. J'ai conservé la dénomination sous laquelle elle est généralement connue pour éviter tout confusion.

*Paracentrotus angulosus* (Leske).

Voir pour la bibliographie :

DÖDERLEIN, *Die Echinoideen der deutschen Tiefsee Expedition*, p. 124.

Baie de Saldanha (Cap) et Cape Town. Plusieurs échantillons.

Cette espèce a été récemment étudiée d'une manière très complète par DÖDERLEIN et je n'ai rien à ajouter à sa description.

*Pseudoboletia maculata*, Troschel. (Pl. XV. figs. 139 à 142 ; Pl. XVI. fig. 165.)

TROSCHEL, *Verh. naturh. Ver. für Rheinland und Westphalie*, vol. xxvi., 1869, p. 96.
J. BELL, "On the Species of Pseudoboletia," *Ann. Mag. Nat. Hist.* (5), vol. xiii., 1884, p. 108.
LORIOL, "Catalogue raisonné des Échinodermes de l'île Maurice," *Mém. Soc. Phys. et Hist. Nat. Genève*, vol. xxviii., 1883, p. 28.
MORTENSEN, *The Danish Ingolf Expedition : Echinoidea*, i., p. 118.

10 Juin 1904, Pointe Pyramid, Ascension ; profondeur 40 brasses. Deux échantillons.

J'avais été très embarrassé pour déterminer ces deux Oursins, le genre *Pseudoboletia* étant considéré par tous les auteurs comme propre au domaine Indo-Pacifique. Fort heureusement, mon excellent ami MORTENSEN, qui a bien voulu les examiner, m'a appris qu'ils étaient identiques au type de la *Ps. maculata* qu'il avait précédemment étudié au British Museum et sur lequel il a donné quelques renseignements dans le travail cité plus haut, en montrant que cette espèce devait être distinguée de la *Ps. indiana*, avec laquelle elle était généralement confondue.

Comme la *Ps. maculata* n'a jamais été décrite, il m'a paru utile de décrire et de représenter les deux exemplaires recueillis par la *Scotia*. En effet, TROSCHEL s'est borné à mentionner l'espèce en indiquant seulement que les entailles péristomiennes ne dépassent pas le septième du diamètre du péristome. Aussi l'espèce n'est elle connue que par les remarques publiées par MORTENSEN.

TROSCHEL n'a pas indiqué l'origine de la *Ps. maculata*, et l'exemplaire du British Museum ne porte aucune indication de localité. La découverte, par la *Scotia*, de cette espèce à l'Ascension est donc très intéressante, car elle ne fixe pas seulement son origine, mais elle montre en outre que le genre *Pseudoboletia*, qu'on croyait propre au domaine Indo-Pacifique, peut aussi se rencontrer dans l'Atlantique.

Le plus grand individu rapporté par la *Scotia* est en excellent état et il a conservé ses piquants, mais ceux-ci sont généralement brisés à l'extrémité. L'autre, un peu plus

petit, a le test complètement dépouillé : c'est celui que j'ai représenté (Pl. XV. fig. 139 à 141, et Pl. XVI. fig. 165.)

Voici les dimensions respectives de ces deux individus :

| | | |
|---|---|---|
| Hauteur, | 24 millim., | 20 millim. |
| Diamètre, | 65 „ | 53 „ |

Le test est très surbaissé et son contour est subpentagonal ; la face ventrale est aplatie. Les aires ambulacraires, à peu près aussi larges que la moitié des aires interambulacraires, comprennent une trentaine de plaques. Chacune de celles-ci porte un tubercule primaire très rapproché de la zone porifère ; entre celui-ci et l'arc de pores, se montre un autre tubercule, qui est d'abord très petit et peut même manquer sur les premières plaques ambulacraires, mais dont les dimensions augmentent au fur et à mesure qu'on se rapproche de l'ambitus où il atteint la taille d'un tubercule secondaire. De l'autre côté, les plaques présentent un autre tubercule dont les dimensions augmentent rapidement de manière à atteindre à peu près la taille du tubercule principal à l'ambitus. Tout le reste de la plaque est occupé par des tubercules secondaires et miliaires assez serrés. Au dessus de l'ambitus, le milieu des zones ambulacraires n'offre que très peu de tubercules. Chaque zone présente donc à l'ambitus quatre tubercules à peu près égaux. Les pores sont disposés en arcs de cinq paires (fig. 141).

Les zones interambulacraires sont très larges et elles renferment chacune vingt-cinq paires de plaques. Chaque plaque porte, vers son bord externe, un tubercule primaire dont les dimensions ne diminuent pas beaucoup vers l'appareil apical. En dehors de cette rangée principale, c'est à dire entre elle et la zone porifère, on remarque une deuxième rangée qui commence sur les premières plaques par des tubercules très petits, mais dont les dimensions augmentent progressivement de manière à égaler, à l'ambitus, les tubercules de la première rangée. De l'autre côté de cette rangée principale, il en existe une troisième qui n'apparait que vers la septième plaque et dont les tubercules augmentent rapidement, de manière à égaler les deux rangées précédentes à l'ambitus. Enfin, en dedans de cette troisième rangée, on en trouve une quatrième, qui apparait encore plus loin que la précédente de l'appareil apical et qui atteint, à l'ambitus, une taille presqu'égale à celle des trois autres ; cette dernière ne se continue pas bien loin au dessous de l'ambitus. On voit donc, qu'à l'ambitus, chaque plaque interambulacraire offre une série de quatre tubercules primaires subégaux. Le reste des plaques est couvert de tubercules secondaires et miliaires, assez serrés à l'ambitus et au dessous, mais beaucoup moins nombreux en dessus, de telle sorte que le milieu des zones interambulacraires est un peu dénudé.

L'appareil apical est petit et ressemble à celui de la *Ps. indiana*. Les plaques génitales sont pentagonales et inégales ; les pores génitaux sont gros et ovalaires. La plaque qui porte le corps madréporique est la plus grosse et elle offre, en dedans de ce corps, trois petits tubercules alignés. La plaque antérieure gauche, allongée, offre un

gros tubercule primaire, entouré de tubercules miliaires ; les autres plaques présentent des dispositions analogues, mais le tubercule principal est plus petit. Deux plaques ocellaires touchent au périprocte : elles sont à peu près rectangulaires et un peu plus grandes que les autres, qui sont pentagonales avec un angle proximal ; elles sont couvertes de petits tubercules. Le périprocte est petit, ovalaire, couvert de plaques assez grandes, mais qui deviennent rapidement plus petites au voisinage de l'anus : elles offrent un tubercule principal et deux ou trois autres plus petits.

Le péristome est grand et il mesure 19 millim. de diamètre sur le plus petit exemplaire. Les entailles sont peu profondes et elles n'ont guère plus de 2 millim. : elles sont donc un peu plus courtes que ne l'indique TROSCHEL, d'après lequel elles sont égales au septième du diamètre du péristome. Elles sont un peu plus fortement marginées d'un côté que de l'autre. Les dix plaques buccales sont grandes et circulaires ; elles présentent une dépression centrale entourée d'un cercle de cinq tubercules principaux portant des piquants allongés ; il y a en plus quelques tubercules miliaires portant des pédicellaires. Le reste de la membrane buccale est couvert de plaquettes, petites, très nombreuses et serrées en dedans du cercle des dix plaques buccales, plus grandes et plus espacées en dehors : ces dernières offrent chacune un petit tubercule.

Les piquants sont presque tous cassés à l'extrémité ; ceux qui restent entiers sur la face ventrale mesurent 12 à 15 millim. de longueur. Ces piquants se terminent par une extrémité tronquée très légèrement élargie ; leur surface est très finement striée et ils offrent des bandes alternativement blanches et vert-pâle, les premières plus larges. A l'ambitus et sur la face dorsale, les piquants sont d'un brun-pourpre sur leur premier tiers et le reste est blanc avec parfois une bande violet-clair.

Le test dénudé offre une couleur blanche sur la face ventrale. Sur la face dorsale, le milieu des aires ambulacraires et interambulacraires est blanc, mais on remarque des parties brun-clair qui forment des taches allongées sur les zones porifères ; il y a en outre, immédiatement au dessus de l'ambitus, cinq taches élargies transversalement sur chaque zone interambulacraire.

Les pédicellaires ont déjà été décrits par MORTENSEN. Les pédicellaires globifères, très peu nombreux, ressemblent à ceux de la *Ps. indiana* ; les pédicellaires tridactyles ne sont pas non plus très abondants. En revanche, j'observe sur le grand exemplaire une quantité considérable de pédicellaires glandulaires volumineux, mais réduits à trois grosses glandes arrondies, sans la moindre indication de rudiments de valves calcaires (Pl. XV. fig. 142). La paroi de ces glandes est bourrée de corpuscules en C élargis aux extrémités, identiques à ceux que présentent les pédicellaires globifères. On retrouve aussi ces corpuscules dans le tégument de la tige : celle-ci se continue entre les trois glandes sous forme d'un bâtonnet qui se termine par une extrémité élargie.

LYON, *le* 8 *Juillet* 1907.

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Fig. 93. „ „ Face ventrale. G. = 4.
Fig. 94. *Ophioglypha partita.* Face dorsale. G. = 1·5.
Fig. 95. „ „ Face ventrale. G. = 5.

### Planche XI.

Fig. 96. *Ophioglypha inops.* Face dorsale. G. = 4.
Fig. 97. „ „ Face ventrale. G. = 5.
Fig. 98. *Ophioglypha scissa.* Face dorsale. G. = 3.
Fig 99. „ „ Face ventrale. G. = 3·5.
Fig. 100. *Ophiocten Ludwigi.* Face dorsale. G. = 55.
Fig. 101. „ „ Face ventrale. G. = 5.
Fig. 102. *Ophiernus quadrispinus.* Face dorsale. G. = 4·5.
Fig. 103. „ „ Face ventrale. G. = 6.
Fig. 104. *Amphiura magellanica.* Face ventrale. G. = 16.

### Planche XII.

Fig. 105. *Cribrella ornata.* Face dorsale. Grandeur naturelle.
Fig. 106. „ „ Face ventrale. G. = 2.
Fig. 107. *Moiraster magnificus.* Face dorsale. Grandeur naturelle.
Fig. 108. „ „ Face ventrale. Grandeur naturelle.
Fig. 109. „ „ Portion de la face dorsale. G. = 5.
Fig. 110. „ „ Portion de la face ventrale. G. = 5.
Fig. 111. *Amphiura magnifica.* Face dorsale grossie un peu plus de 2 fois.
Fig. 112. *Ophioglypha scissa.* Face ventrale. G. = 3.

### Planche XIII.

Fig. 113. *Amphilepis antarctica.* Face dorsale. G. = 30.
Fig. 114. „ „ Face ventrale. G. = 30.
Fig. 115. *Amphiura murex.* Face dorsale. G. = 28.
Fig. 116. „ „ Face ventrale. G. = 28.
Fig. 117. *Amphiura consors.* Face dorsale. G. = 3·5.
Fig. 118. „ „ Face ventrale. G. = 4·5.
Fig. 119. *Amphiura magnifica.* Face ventrale grossie un peu plus de 3 fois.
Fig. 120. *Astrotoma Agassizii.* Face dorsale d'un très jeune individu. G. = 5.

### Planche XIV.

| | | |
|---|---|---|
| Fig. 121. | *Amphiura Mortenseni.* | Face dorsale. G. = 6. |
| Fig. 122. | ,, ,, | Face ventrale. G. = 18. |
| Fig. 123. | *Ophiacantha frigida.* | Face dorsale. G. = 10. |
| Fig. 124. | ,, ,, | Face ventrale. G. = 10. |
| Fig. 125. | ,, ,, | Piquants de la face dorsale du disque. G. = 80. |
| Fig. 126. | *Ophiomitrella ingrata.* | Face dorsale. G. = 24. |
| Fig. 127. | ,, ,, | Face ventrale. G. = 24. |
| Fig. 128. | *Ophiacantha opulenta.* | Face dorsale. G. = 4. |
| Fig. 129. | ,, ,, | Face ventrale. G. = 4·5. |

### Planche XV.

| | | |
|---|---|---|
| Fig. 130. | *Delopatagus Brucei.* | Face dorsale. G. = 2. |
| Fig. 131. | ,, ,, | Face ventrale. G. = 2. |
| Fig. 132. | ,, ,, | Face latérale. G. = 2. |
| Fig. 133. | ,, ,, | Face postérieure. G. = 2. |
| Fig. 134. | ,, ,, | Gros pédicellaire rostré. G. = 85. |
| Fig. 135. | ,, ,, | Pédicellaire tridactyle. G. = 85. |
| Fig. 136. | *Cidaris minor.* | Face dorsale. G. = 2·5. |
| Fig. 137. | ,, ,, | Face latérale. G. = 2·5. |
| Fig. 138. | ,, ,, | Pédicellaire globifère. G. = 240. |
| Fig. 139. | *Pseudoboletia maculata.* | Face dorsale légèrement grossie. |
| Fig. 140. | ,, ,, | Face latérale légèrement grossie. |
| Fig. 141. | ,, ,, | Portion du test à l'ambitus. G. = 4. |
| Fig. 142. | ,, ,, | Pédicellaire glandulaire. G. = 40. |

### Planche XVI.

| | | |
|---|---|---|
| Fig. 143. | *Sterechinus Neumayeri.* | Vue latérale d'un exemplaire en partie dépouillé de ses piquants. Grandeur naturelle. |
| Fig. 144. | ,, ,, | Portion du test à l'ambitus. G. = 5. |
| Fig. 145. | *Hemiaster elongatus.* | Face dorsale du grand exemplaire. Grandeur naturelle. |
| Fig. 146. | ,, ,, | Face laterale du même exemplaire. |
| Fig. 147. | ,, ,, | Face ventrale du même. |
| Fig. 148. | ,, ,, | Face postérieure du même. |
| Fig. 149. | ,, ,, | Face ventrale d'un exemplaire un peu plus petit et en partie dépouillé de ses piquants. Grandeur naturelle. |
| Fig. 150. | ,, ,, | Face dorsale du même exemplaire. |
| Fig. 151. | ,, ,, | Face dorsale du petit exemplaire. Grandeur naturelle. |
| Fig. 152. | ,, ,, | Face latérale du même exemplaire. |
| Fig. 153. | ,, ,, | Face ventrale du même exemplaire. |
| Fig. 154. | ,, ,, | Pédicellaire globifère. G. = 40. |
| Fig. 155. | ,, ,, | Pédicellaire rostré. G. = 62. |
| Fig. 156. | ,, ,, | Pédicellaire tridactyle. G. = 62. |
| Fig. 157. | ,, ,, | Valve isolée d'un petit pédicellaire tridactyle. G. = 62. |
| Fig. 158. | ,, ,, | Pédicellaire trifolié G. = 130. |
| Fig. 159. | *Urechinus fragilis.* | Face dorsale. Grossie près de 2 fois. |
| Fig. 160. | ,, ,, | Face ventrale. Même grossissement. |
| Fig. 161. | ,, ,, | Face latérale. Même grossissement. |
| Fig. 162. | ,, ,, | Pédicellaire tridactyle. G. = 85. |
| Fig. 163. | *Tretocidaris spinosa.* | Face dorsale. Grandeur naturelle. |
| Fig. 164. | ,, ,, | Face latérale. Grandeur naturelle. |
| Fig. 165. | *Pseudoboletia maculata.* | Face ventrale légèrement grossie. |

KŒHLER: ÉCHINODERMES DE L'EXPÉDITION ANTARCTIQUE NATIONALE ÉCOSSAISE—PLANCHE I.

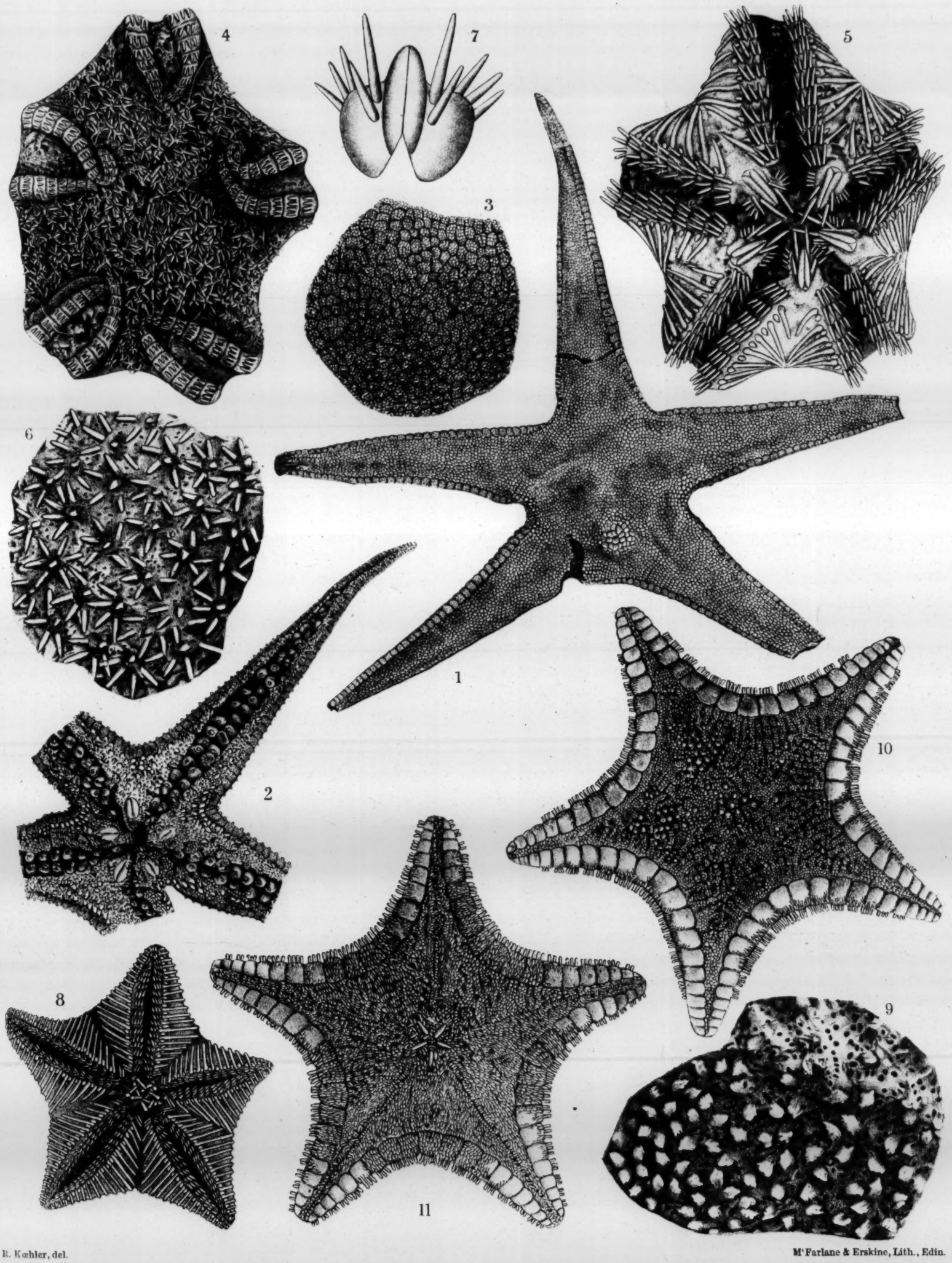


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Fig. 1, 2 et 3. Dytaster felix.
Fig. 8 et 9. Hymenaster campanulatus.

Fig. 4 à 7. Hymenaster densus.
Fig. 10 et 11. Odontaster pusillus.

KŒHLER: ÉCHINODERMES DE L'EXPÉDITION ANTARCTIQUE NATIONALE ÉCOSSAISE—PLANCHE II.

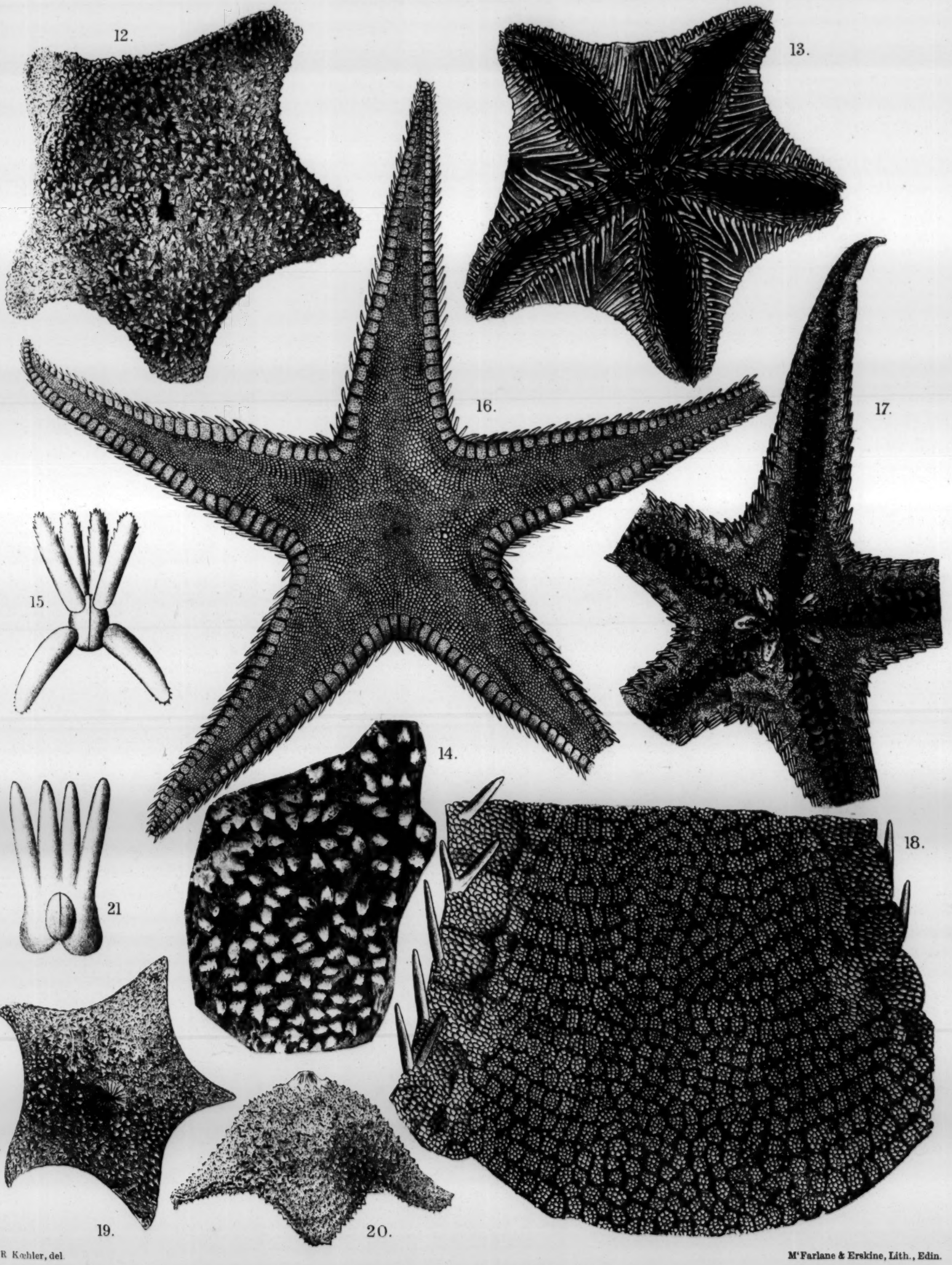


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Fig. 12 à 15. Hymenaster edax. Fig. 16, 17 et 18. Psilasteropsis facetus.
Fig. 19, 20 et 21. Hymenaster campanulatus.

KŒHLER: ÉCHINODERMES DE L'EXPÉDITION ANTARCTIQUE NATIONALE ÉCOSSAISE—PLANCHE III.

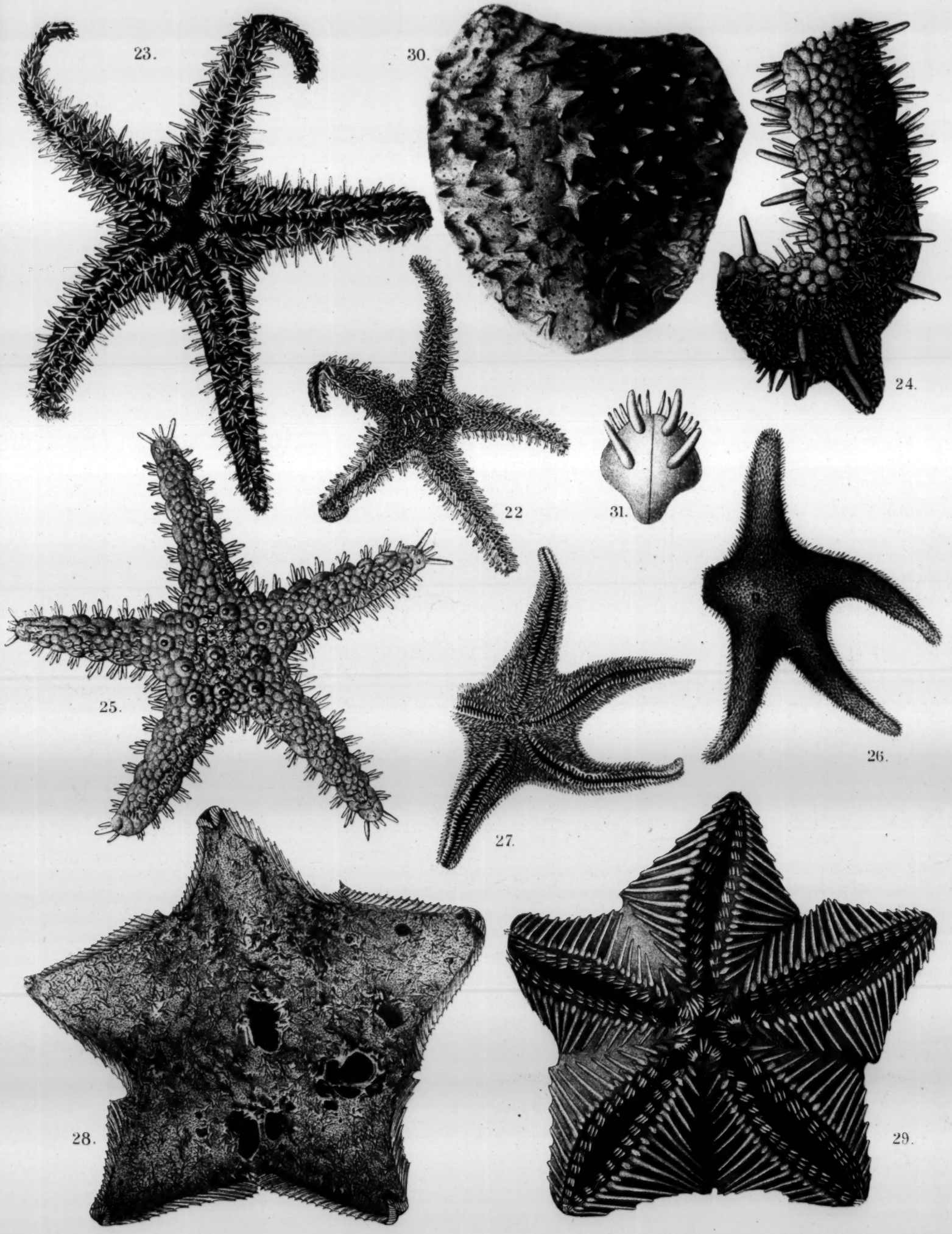


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Fig. 22 à 25. Marcelaster antarcticus. Fig. 26 et 27. Ganeria attenuata.
Fig. 28 à 31. Hymenaster fucatus.

KŒHLER: ÉCHINODERMES DE L'EXPÉDITION ANTARCTIQUE NATIONALE ÉCOSSAISE—PLANCHE IV.

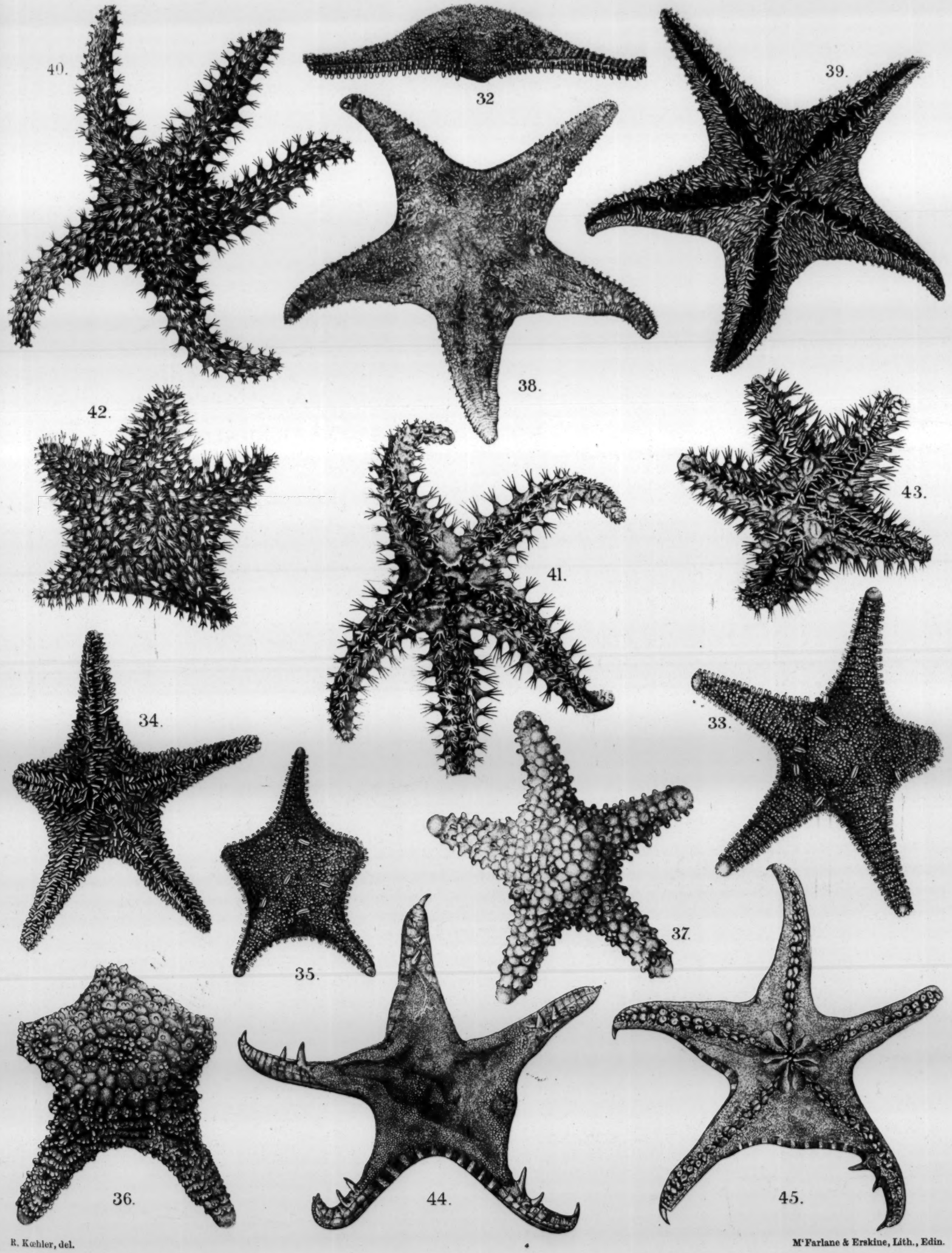


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Fig. 32 à 37. Chitonaster Johannæ.
Fig. 40 et 41. Solaster Lorioli.

Fig. 38 et 39. Scotiaster inornatus.
Fig. 42 et 43. Lophaster abbreviatus.

KŒHLER: ÉCHINODERMES DE L'EXPÉDITION ANTARCTIQUE NATIONALE ÉCOSSAISE—PLANCHE V.

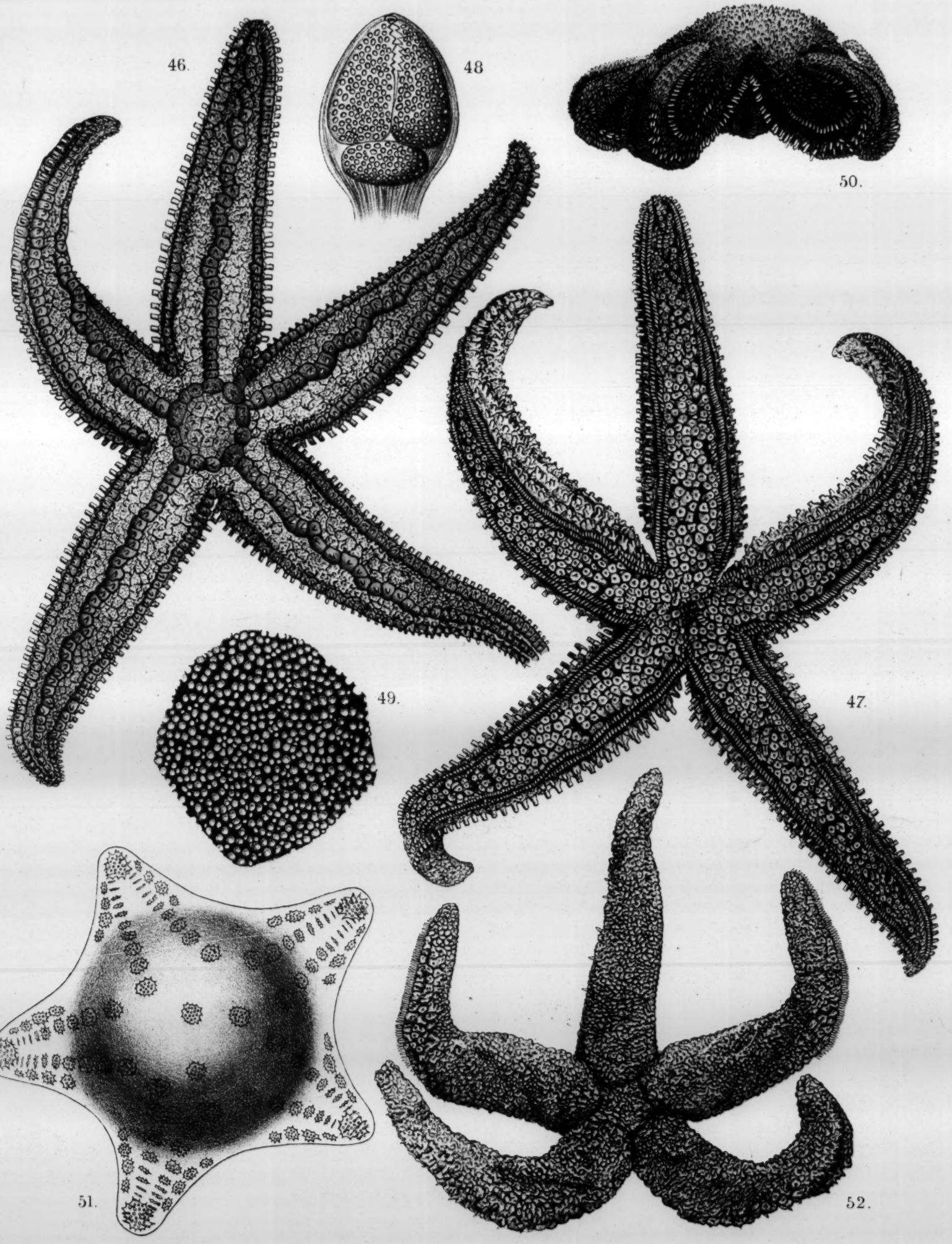


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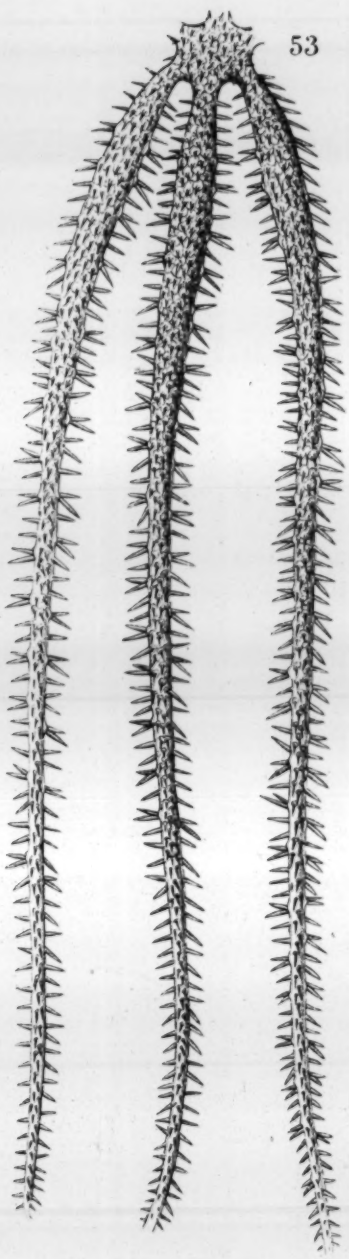
Fig. 46 et 47. Stolasterias Brucei.
Fig. 48 et 49. Granaster biseriatus.
Fig. 50 et 51. Diplasterias Brandtii.
Fig. 52. Anasterias cupulifera.

KŒHLER: ÉCHINODERMES DE L'EXPÉDITION ANTARCTIQUE NATIONALE ÉCOSSAISE—PLANCHE VI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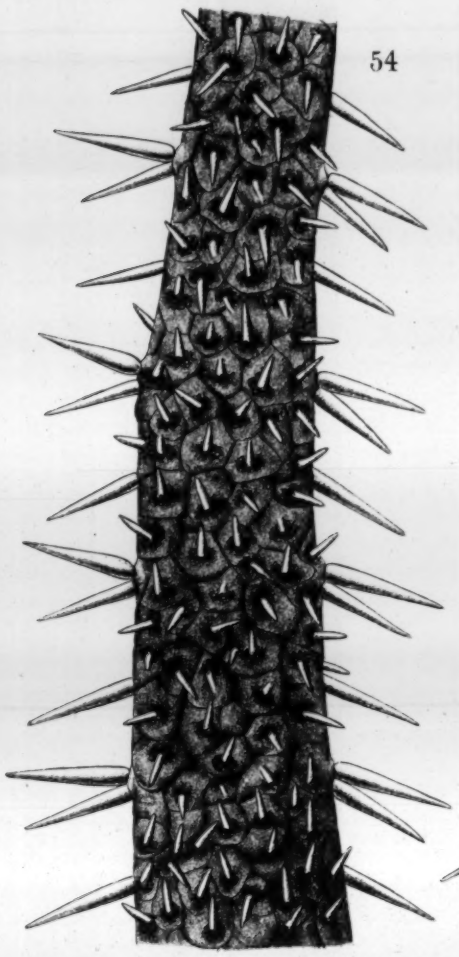
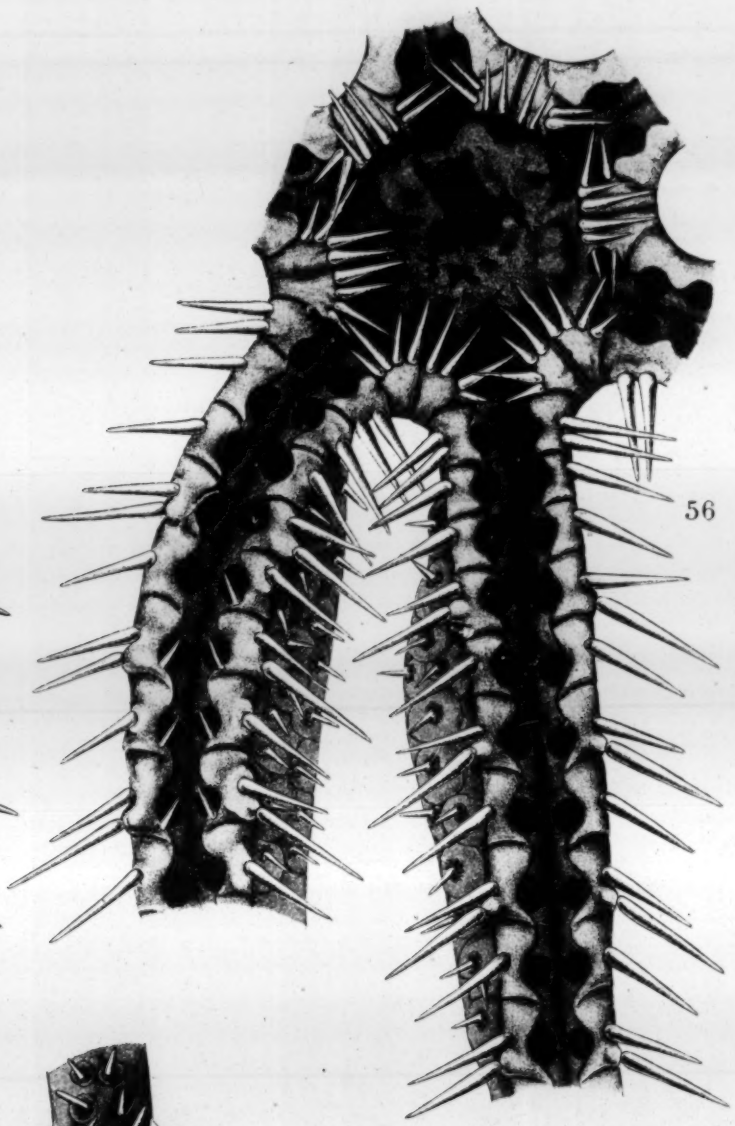

54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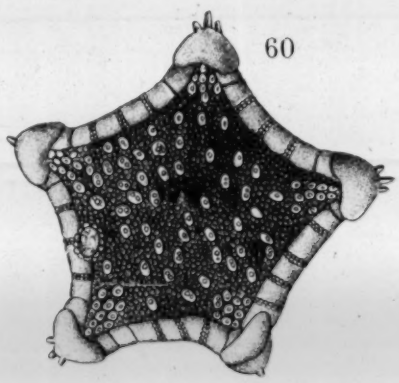
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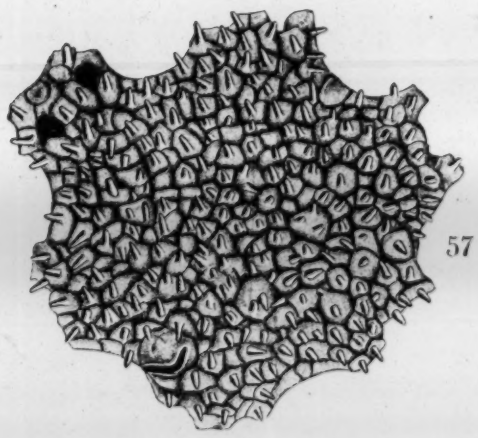
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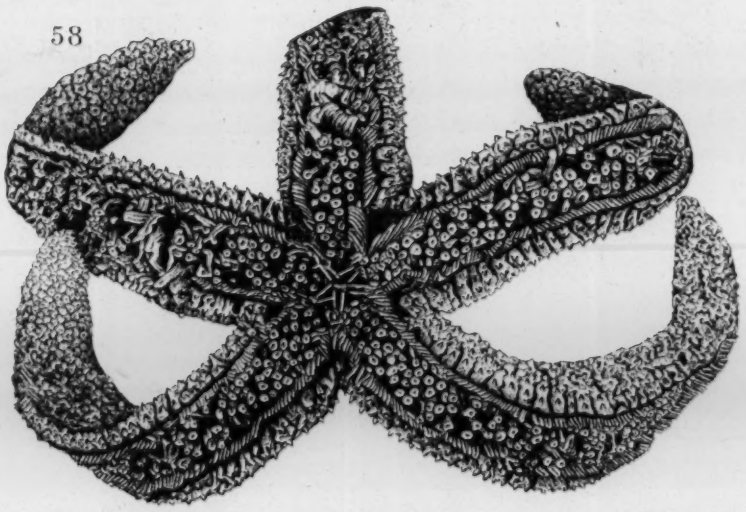
58

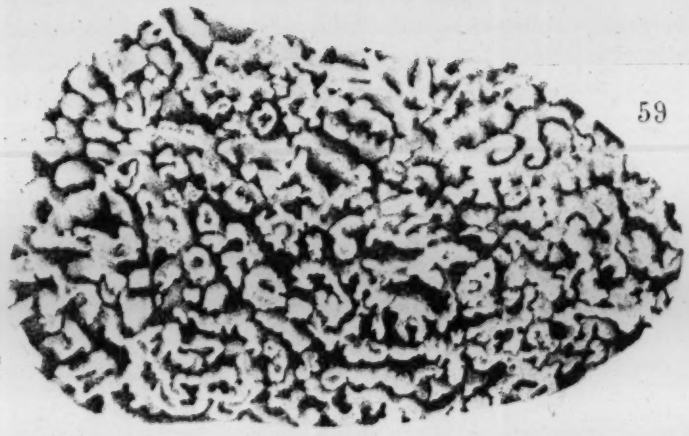
59

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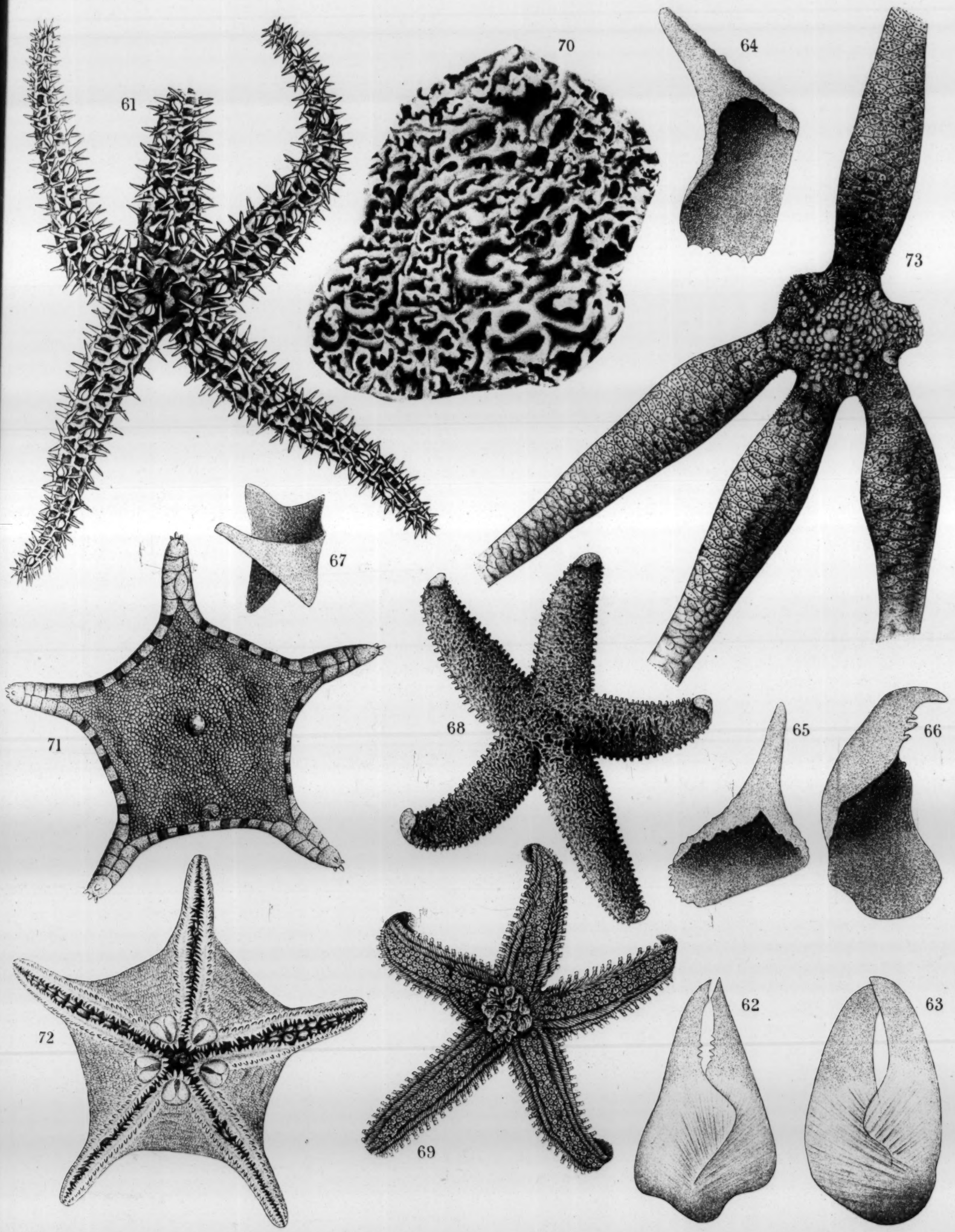
Fig. 53–57. Freyella Giardi. Fig. 58, 59. Anasterias cupulifera. Fig. 60. Hyphalaster Scotiæ

KŒHLER: ÉCHINODERMES DE L'EXPÉDITION ANTARCTIQUE NATIONALE ÉCOSSAISE—PLANCHE VII.

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M'Farlane & Erskine, Lith., Edin.

Fig. 61–67. Asterias pedicellaris. Fig. 68–70. Diplasterias induta. Fig. 71, 72. Hyphalaster Scotiæ.
Fig. 73. Belgicella Racovitzana.

KŒHLER : ÉCHINODERMES DE L'EXPÉDITION ANTARCTIQUE NATIONALE ÉCOSSAISE—PLANCHE VIII.

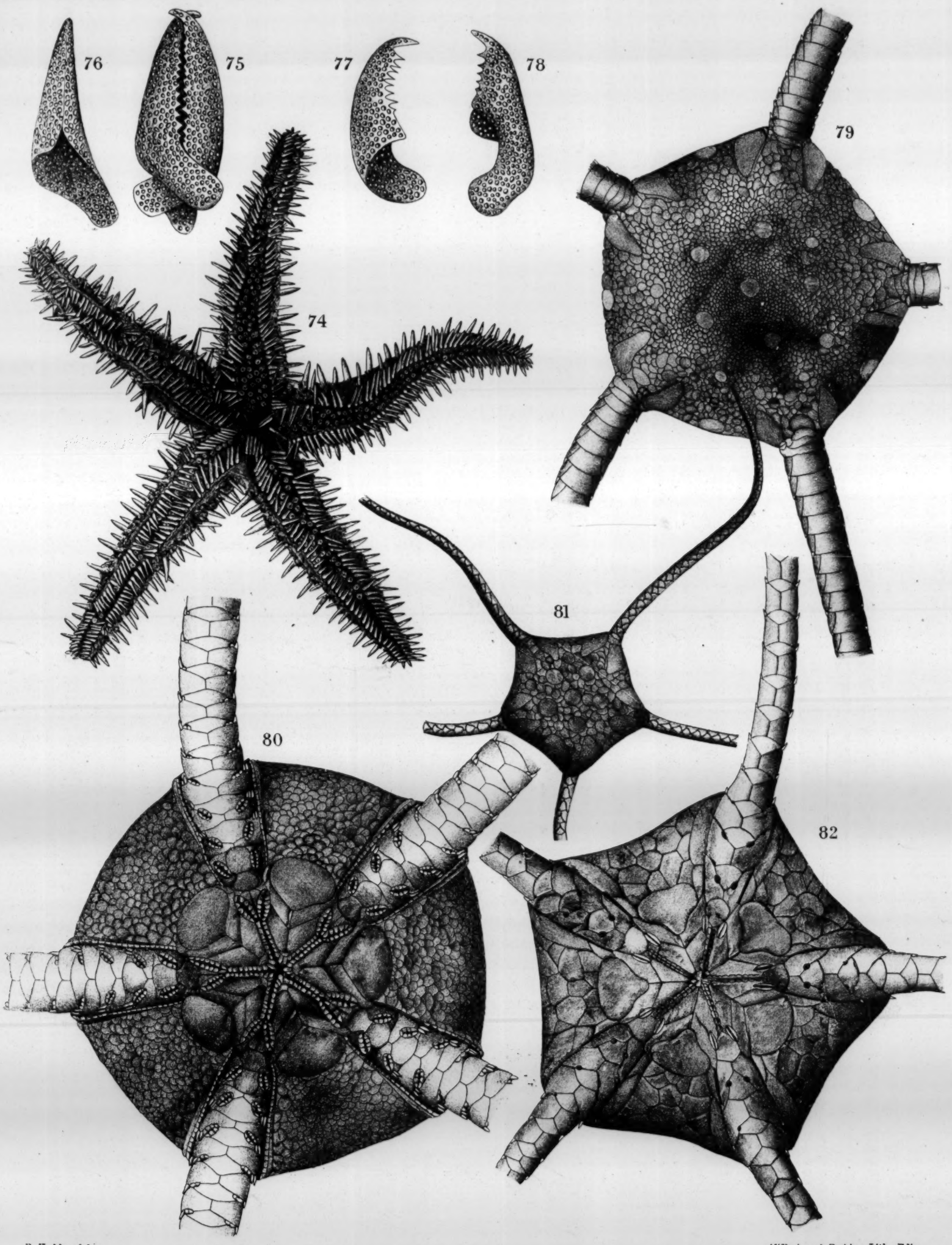


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Fig. 74 à 78. Asterias pedicellaris. Fig. 79 et 80. Ophioglypha integra. Fig. 81 et 82. Ophioglypha Brucei.

KŒHLER: ÉCHINODERMES DE L'EXPÉDITION ANTARCTIQUE NATIONALE ÉCOSSAISE—PLANCHE IX.

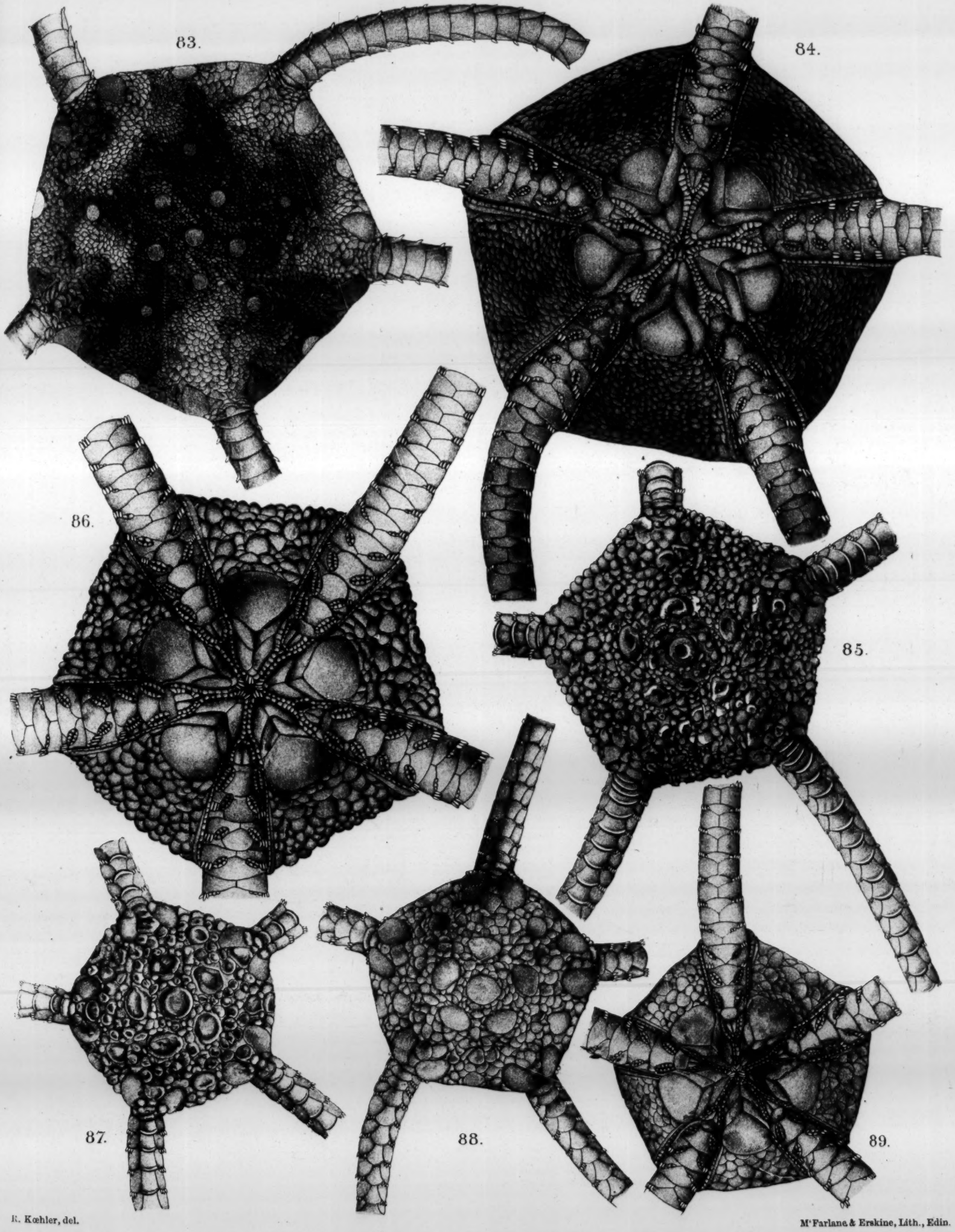


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Fig. 83 et 84. Ophioglypha figurata. Fig. 85, 86, et 87. Ophioglypha ossiculata.
Fig. 88 et 89. Ophioglypha mimaria.

KŒHLER: ÉCHINODERMES DE L'EXPÉDITION ANTARCTIQUE NATIONALE ÉCOSSAISE—PLANCHE X.

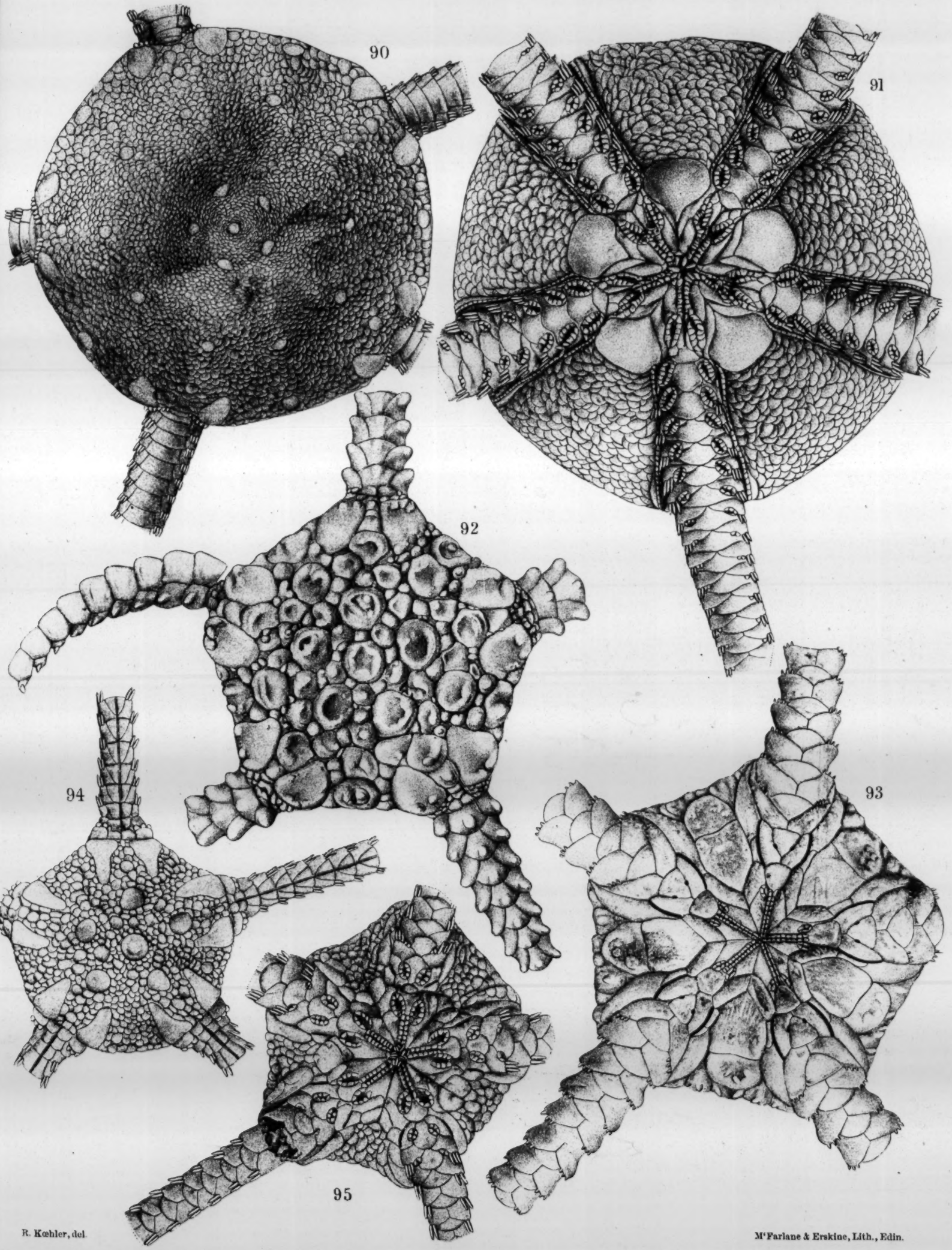



Fig. 90, 91. Ophioglypha lenticularis. Fig. 92, 93. Ophioglypha anceps. Fig. 94, 95. Ophioglypha partita.

KŒHLER: ÉCHINODERMES DE L'EXPÉDITION ANTARCTIQUE NATIONALE ÉCOSSAISE—PLANCHE XI.

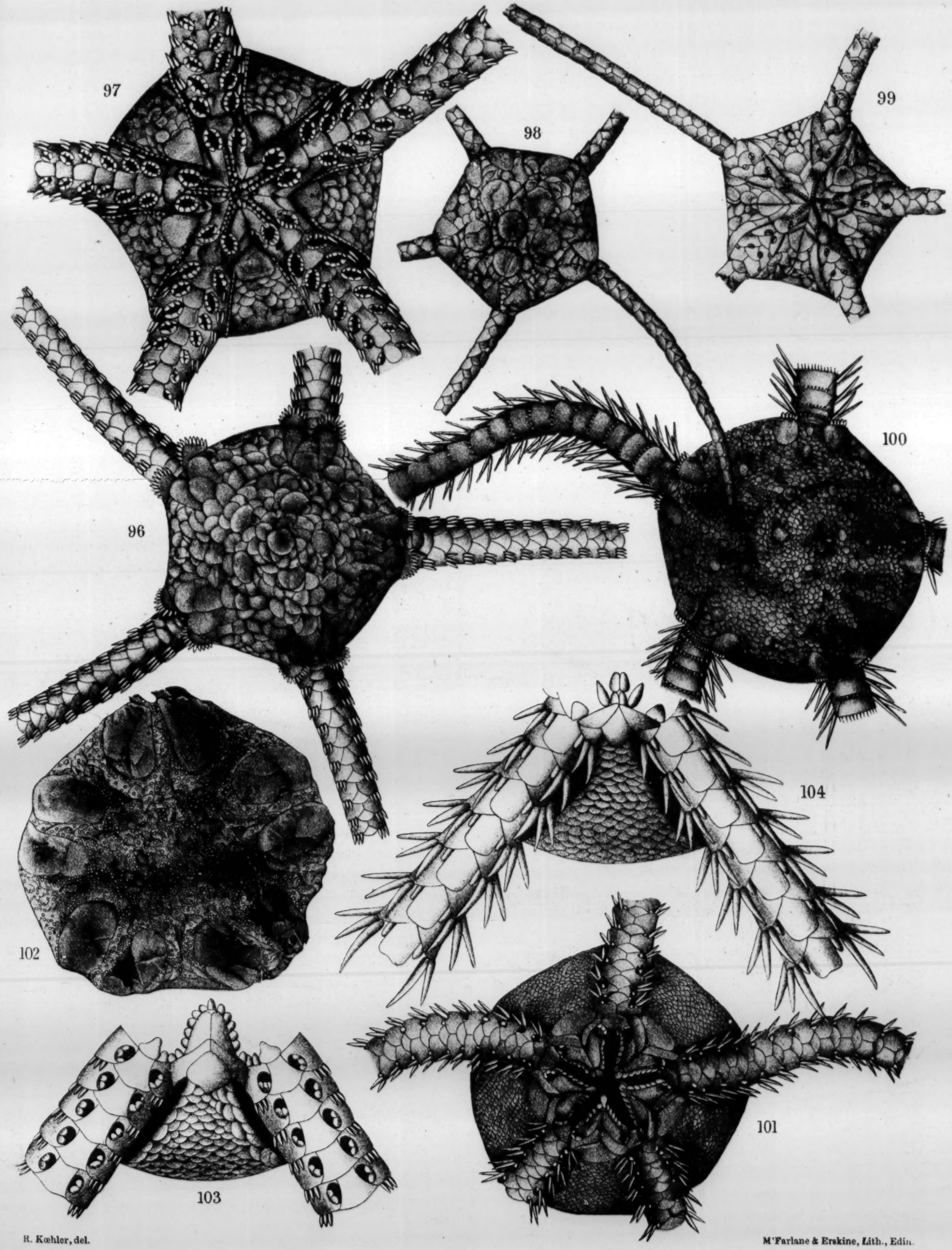



Fig. 96 et 97. Ophioglypha inops. Fig. 98 et 99. Ophioglypha scissa. Fig. 100 et 101. Ophiocten Ludwigi.
Fig. 102 et 103. Ophiernus quadrispinus. Fig. 104. Amphiura magellanica

KŒHLER: ÉCHINODERMES DE L'EXPÉDITION ANTARCTIQUE NATIONALE ÉCOSSAISE—PLANCHE XII.

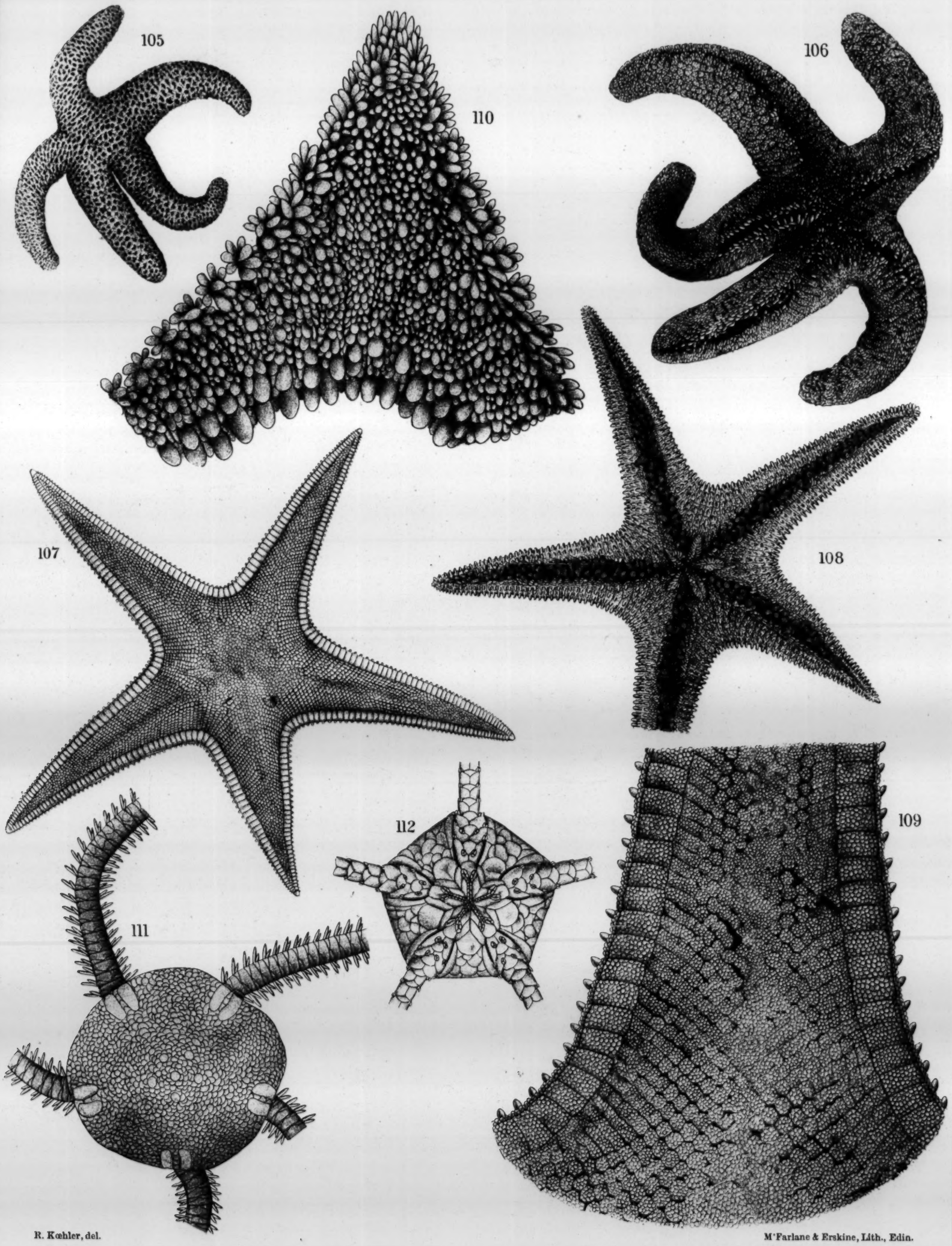
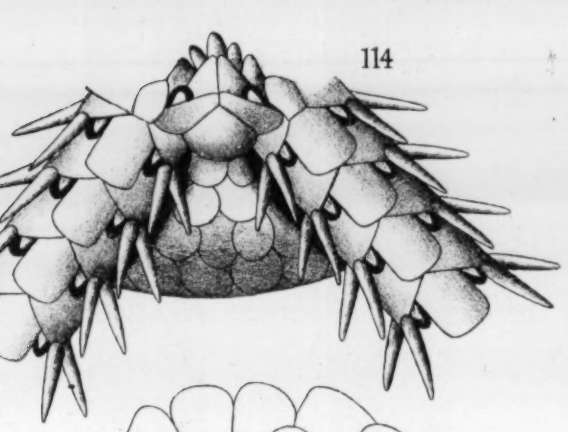
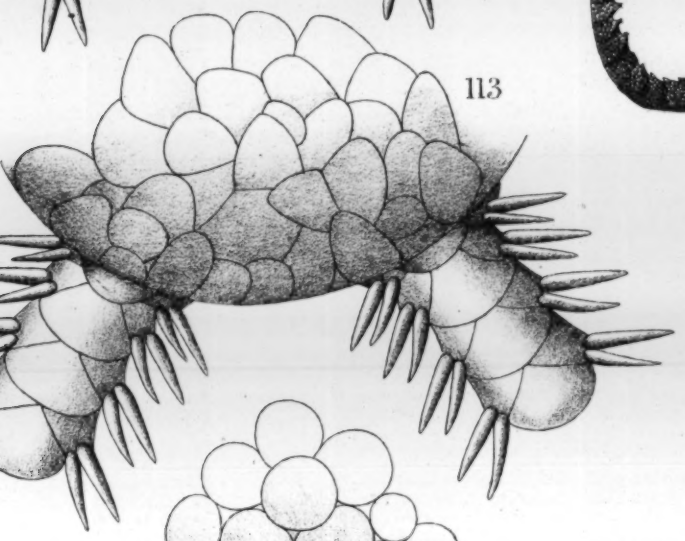
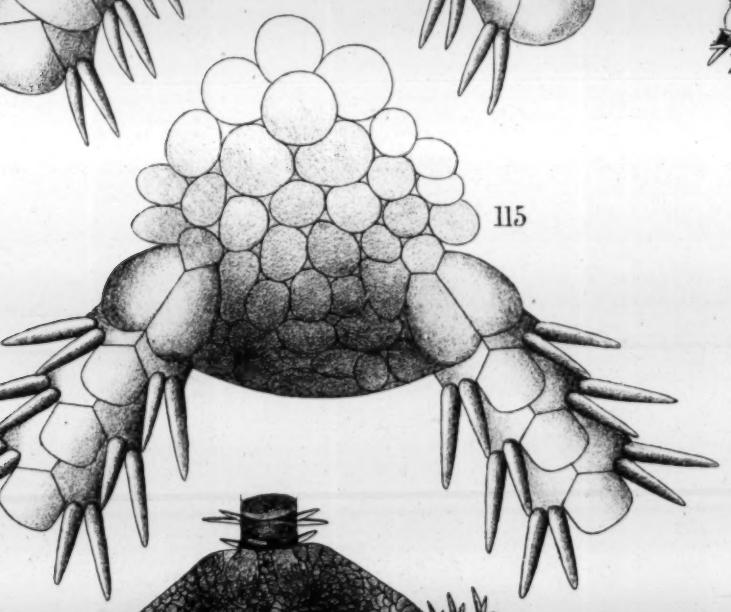
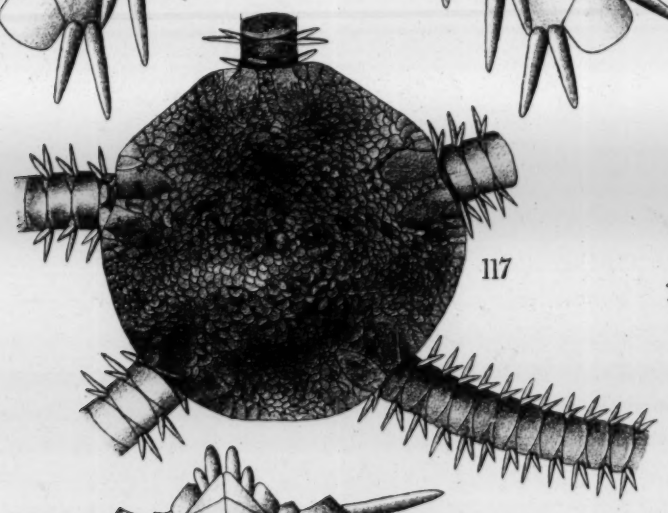


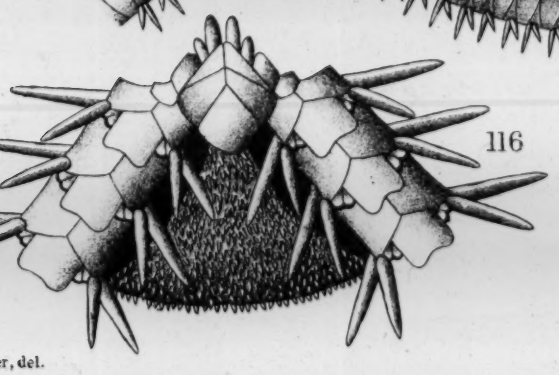

Fig. 105, 106. Cribrella ornata.
Fig. 107 à 110. Moiraster magnificus.
Fig. 111. Amphiura magnifica.
Fig. 112. Ophioglypha scissa.

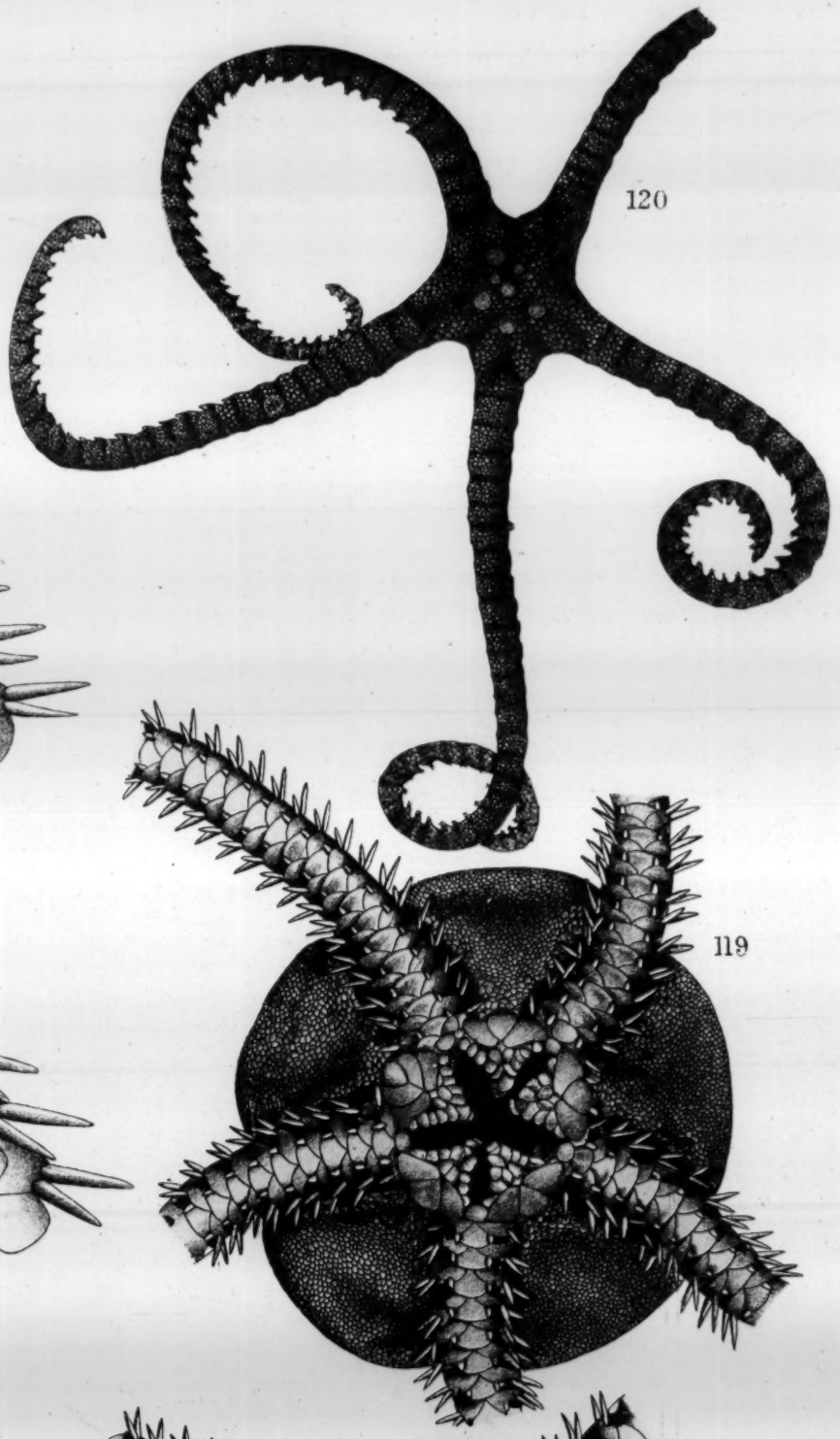


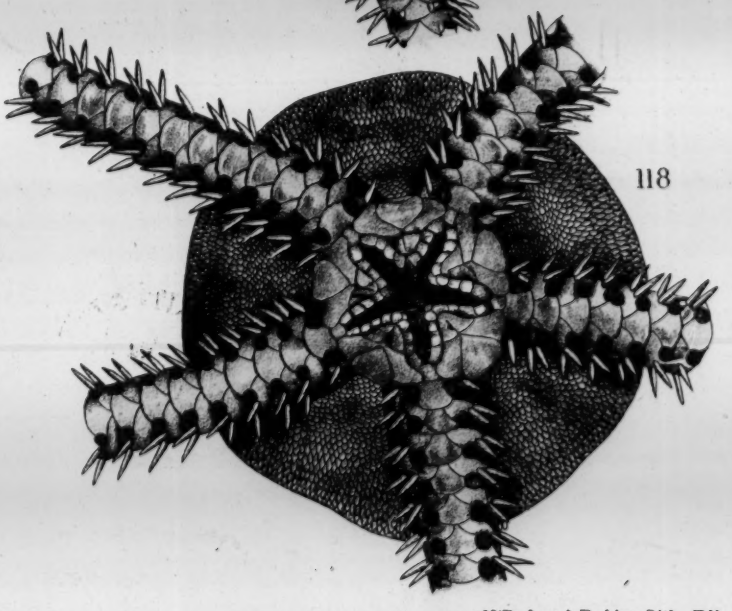

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M'Farlane & Erskine, Lith., Edin.

ig. 113 et 114. Amphilepis antarctica. Fig. 115 et 116. Amphiura murex. Fig. 117 et 118. Amphiura consors.
Fig. 119. Amphiura magnifica. Fig. 120. Astrotoma Agassizii.

KŒHLER : ÉCHINODERMES DE L'EXPÉDITION ANTARCTIQUE NATIONALE ÉCOSSAISE—PLANCHE XIV.

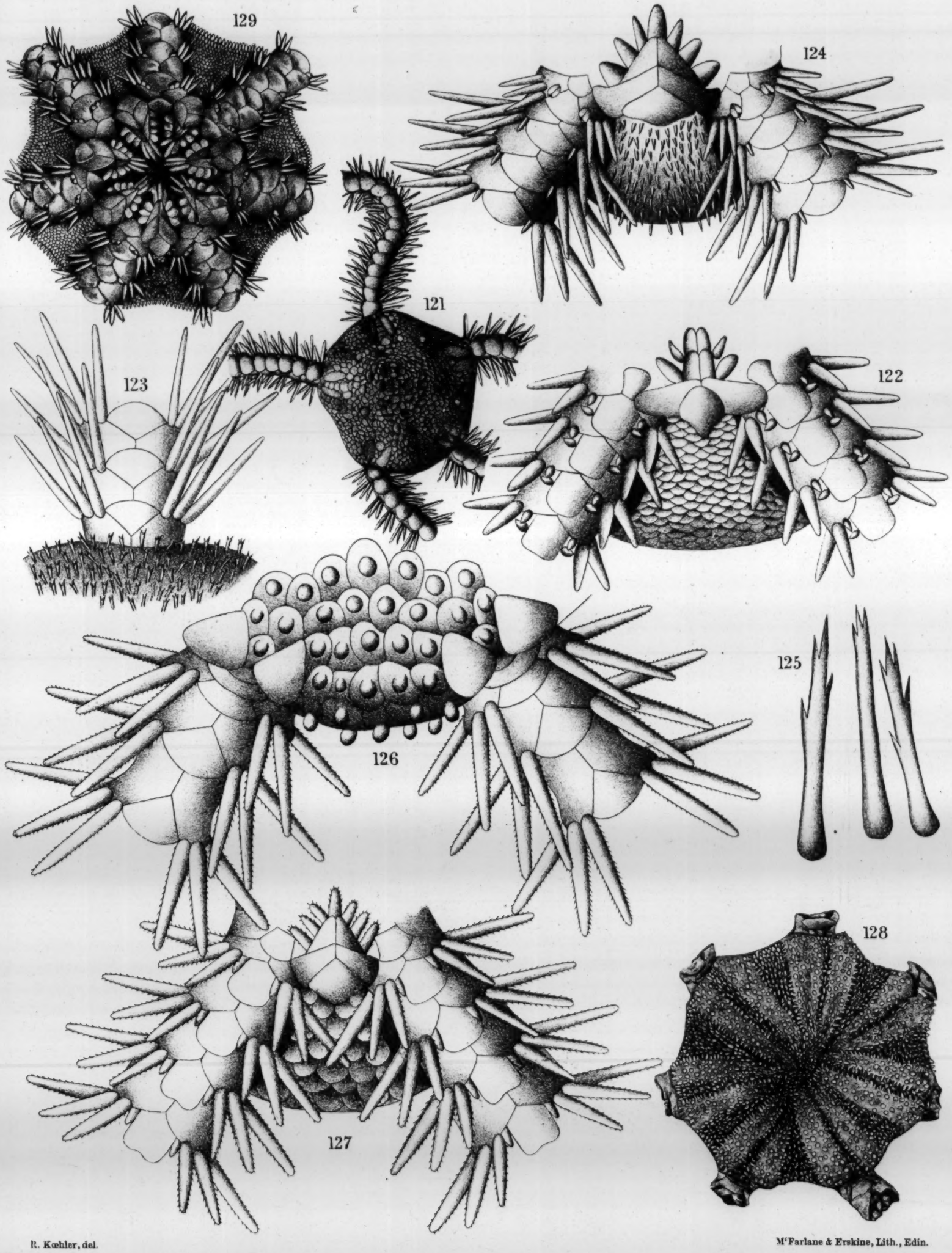


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Fig. 121 et 122. Amphiura Mortenseni.
Fig. 126 et 127. Ophiomitrella ingrata.
Fig. 123 à 125. Ophiacantha frigida.
Fig. 128 et 129. Ophiacantha opulenta.

KŒHLER: ÉCHINODERMES DE L'EXPÉDITION ANTARCTIQUE NATIONALE ÉCOSSAISE—PLANCHE XV.

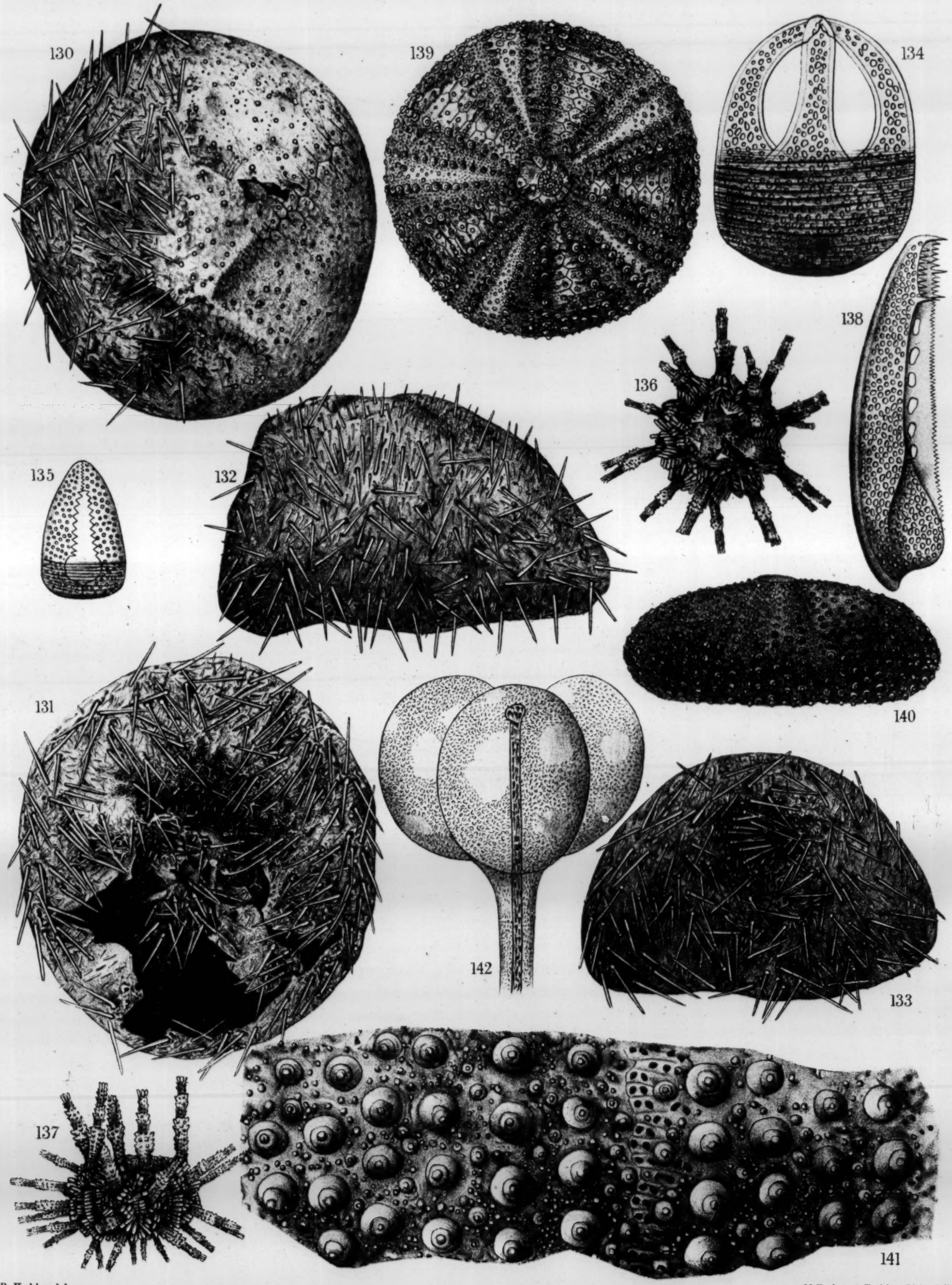


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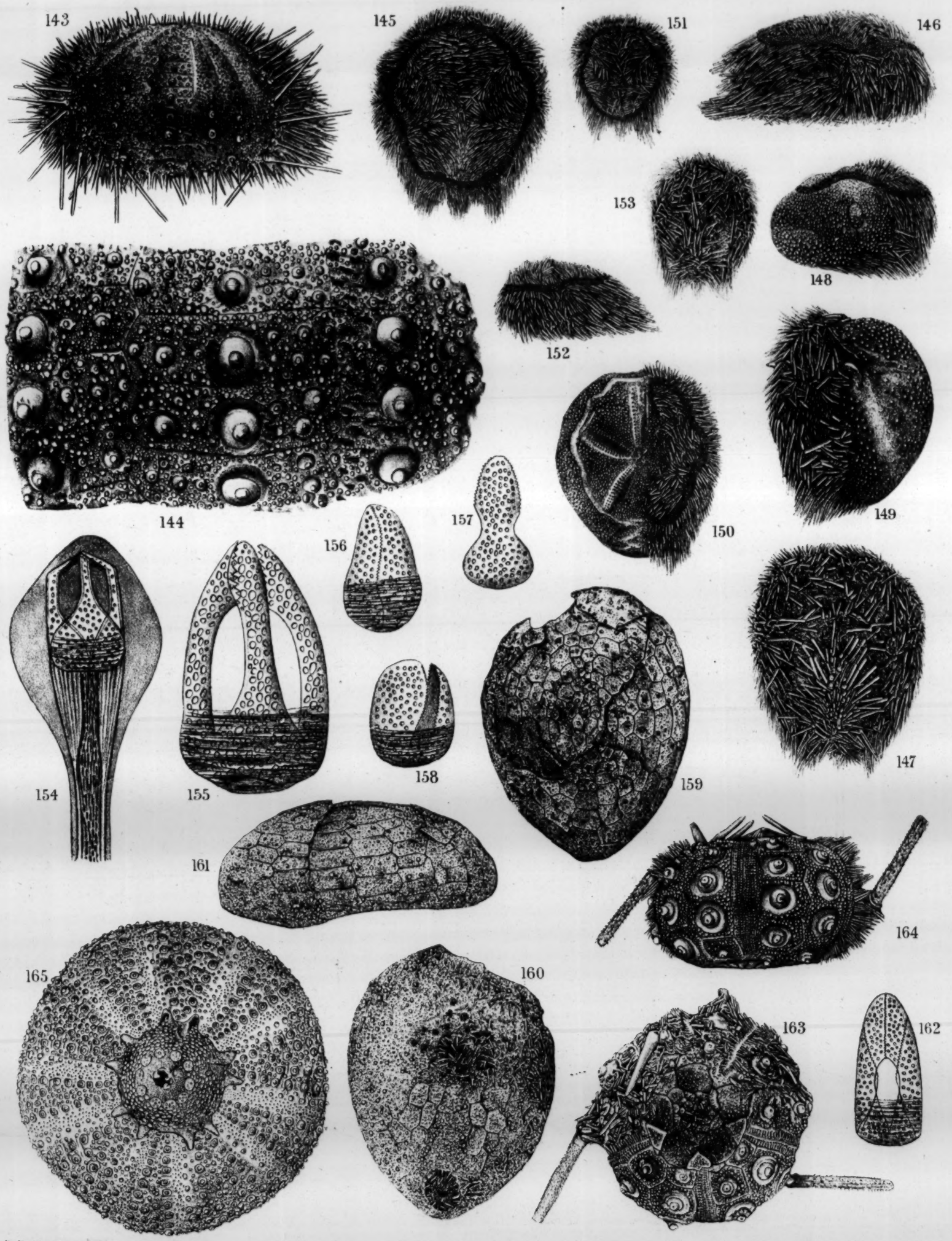
Fig. 130 à 135. Delopatagus Brucei. Fig. 136, 137 et 138. Cidaris minor.
Fig. 139 à 142. Pseudoboletia maculata.

KŒHLER: ÉCHINODERMES DE L'EXPÉDITION ANTARCTIQUE NATIONALE ÉCOSSAISE—PLANCHE XVI.




R. Kœhler. del

M'Farlane & Erskine, Lith., Edin

Fig. 143 et 144. Sterechinus Neumayeri.
Fig. 145 à 158. Hemiaster elongatus.
Fig. 159 à 162. Urechinus fragilis.
Fig. 163 et 164. Tretocidaris spinosa.
Fig. 165. Pseudoboletia maculata.

# XXIII.—On the Fossil Osmundaceæ.

By **R. Kidston**, LL.D., F.R.S. L. & E., F.G.S., Foreign Mem. K. Mineral. Gesell. zu St Petersburg; and **D. T. Gwynne-Vaughan**, M.A., F.L.S., Lecturer in Botany, Birkbeck College, London. (Plates I.–VIII.)

(MS. received November 28, 1908. Read January 4, 1909. Issued separately January 23, 1909.)

## PART III.*

We have already referred in the second part of this series to the opinions held by various authors as to the systematic position of the genera *Thamnopteris*, *Bathypteris*, and *Anomorrhœa*, and have given in detail the reasons that have induced us to adopt these names for the specimens included in these genera (*cf.* Part II., p. 213). It is therefore unnecessary for us to deal any further with the historical aspect of the matter in the present communication, and we will at once proceed to the description of the structure of the Fern stems in question.

### Thamnopteris, Brongniart.

1849. *Tableaux des genres de végét. foss.*, p. 35.

### Thamnopteris Schlechtendalii, Eichwald, sp.

(Pls. I.–V.)

1842. *Anomopteris Schlechtendalii*, Eichwald, *Urwelt Russlands*, Heft ii., St Petersburg, pp. 163–180, pl. iv. figs. 3, 4, and 5.†

1849. *Thamnopteris Schlechtendalii*, Brongt., *Tableaux des genres des végét. foss.*, pp. 35–36.

1850. *Sphalmopteris Schlechtendalii*, Unger, *Genera et species*, p. 195.

1860. *Sphallopteris Schlechtendalii*, Eichwald, *Lethæa Rossica*, vol. i., p. 93, pl. iii. figs. 2 and 3, and pl. xx. figs. 2 and 5.‡

1869. *Thamnopteris Schlechtendalii*, Schimper, *Traité de paléont. végét.*, vol. i., p. 701.

A photograph sent to us by Mons. Zalessky, showing the external characters of the type specimen, is figured half natural size in Pl. II. fig. 2. The portion presented to us for examination by Mons. Tschernyschew was cut from the upper part of this specimen, and is figured natural size in Pl. II. fig. 3. It comprised about two-thirds of the total circumference of the complete specimen (*cf.* Pl. I. fig. 1), which must have measured about 12 cm. across its greatest diameter. The exposed surface of the fossil does not exhibit the true external surface of the original stock. It

* Part I., *Trans. Roy. Soc. Edin.*, vol. xlv., part iii. (No. 27), pp. 759–780, pls. i.–vi., 1907. Part II., *idem*, vol. xlvi., part ii. (No. 9), pp. 213–232, pls. i.–iv., 1908.

† The specimens figured came from the "grès cuivreux" of Kamskowatkinsk, government of Wjatka.

‡ The specimens figured came from the "grès cuivreux" of Bjelebei.

will become evident from the subsequent description that an unknown amount of its coating of leaf-bases has been removed from it. Each leaf-base is clearly delimited on the surface of the fossil, owing to the more persistent nature of the sclerotic tissues of the petiole; and in some of them, for similar reasons, the horseshoe-shaped leaf-trace is also clearly visible. The spirally arranged leaf-traces increase in size quite gradually towards without, not being interrupted by zones of reduced scale leaves as in the living and in certain fossil *Osmundaceæ* (fig. 1). Numerous stout roots are seen here and there boring their way through the leaf-bases in various directions. Impressions of these roots are also to be seen on the outer surface of the fossil, whose arrangement suggests that they frequently branched while still embedded in the petiolar coating, as they also do in the living *Osmundaceæ* (fig. 4). *Osmunda cinnamomea* presents an extreme case of this root-branching, as may be seen in fig. 5 *a* and *b*, which is a photograph of a portion of a branch system dissected out.

## The Histology of the Stem.

The transverse section of our specimen (fig. 1) shows that the plant possessed a large central stele 13 mm. wide. The xylem mass alone measures 11 mm. in diameter, and it consists of two distinct regions. There is an outer ring of normal tracheæ surrounding a central mass of xylem elements of a very special and peculiar type (fig. 1, *o. xy.* and *c. xy.*). These central elements constitute the greater part of the xylem mass, forming a core about 8 mm. in diameter; the width of the outer xylem ring being therefore about 3 mm. The peripheral contour of the whole xylem is somewhat uneven, owing to the progressive increase in prominence of the departing leaf-trace xylems. On the outside of the stele there is a wide parenchymatous inner cortex, the tissue of which has become almost completely disorganised (fig. 1, *i.c.*). This is followed by a somewhat narrower zone of sclerotic outer cortex (fig. 1, *sc. C.*), which by its deep brown colour forms a prominent feature of the fossil and also marks the limit of the stem proper, which is about 50 mm. in diameter. The remainder of the specimen consists of a thick sheath of adpressed and more or less concrescent petiole bases. Only the inner portion of this petiolar coating is present in our specimen, which is bordered by well-preserved fragments of still more pheripheral petioles. Its total extent can only be conjectured, but in the living plant it was probably of considerably greater width.

To return to the stele. The whole mass of the xylem is entirely without any admixture of parenchyma. The elements of the outer xylem zone are very elongated, sharp-pointed tracheæ with regular multiseriate pits (figs. 6–9). The pits are transversely elongated, and two, three, or four vertical series usually occur on the same facet of the tracheal wall (fig. 10). Five or even six series are also occasionally met with, but simple scalariform tracheæ with a single series of pits on each wall are very rare. The tracheæ diminish slightly in size towards the periphery, without,

however, becoming conspicuously small, and even the outermost possess the same kind of pitting as the rest. Elements with small lumens also appear to be scattered throughout the outer xylem, but longitudinal sections show that these are really due to the transversely cut ends of the tapering tracheæ. The only definite protoxylem elements to be observed in the stem stele are those decurrent from the leaf-traces which form more or less deeply immersed groups at various points in the ring of outer xylem (fig. 6). These protoxylem strands consist of small tracheæ with a single series of scalariform pits on their walls, and they die out gradually below without joining on to one another.

The central xylem is sharply marked off from the outer xylem ring both as seen in transverse and in longitudinal section (figs. 6 and 7). The strong contrast it makes with the outer xylem is due to the fact that it consists of short and wide elements very irregular in shape, but on the whole more or less vesicular or sack-like (fig. 11). In transverse section some of these elements appear to be thinner walled than the rest, in particular towards the central region; but longitudinal sections show clearly that the whole of the central xylem consisted originally of entirely similar tracheal elements, and that these apparent differences are the result of variation in the amount of decay undergone by the parts in question before mineralisation. The short tracheal elements of the central xylem were no doubt thinner walled than those of the outer xylem ring, and possibly also less lignified, and they further differed in the nature of their pitting. The distribution of their pits is completely irregular, and they can only be described as reticulate (figs. 12 and 13). It is instructive to contrast these figures with those of the more regular "porose" tracheæ of the central xylem of *Zalesskya gracilis* shown in figs. 5, *g* and *h*, Pl. II., in Part II. of this series. All the elements of the xylem, both central and peripheral, are really vessels, the pits being actual perforations. In the reticulate elements each pit represents a distinct and separate perforation; but when the pits are in regular vertical series all the pits of one series communicate with one another by a split or empty space in the substance of the wall, as is also the case in the other *Osmundaceæ* both recent and fossil.* In *Thamnopteris* the xylem is preserved in such a way that the holes in the middle of the wall appear as light-coloured spaces enclosed in dark-coloured bars that represent the solid regions, giving an effect similar to that we have already figured in *Osmundites skidegatensis* (Part II., Pl. II. fig. 7).

We have no doubt that in the living plant the xylem was quite solid and continuous up to the very centre, although in our sections there is a small central area unoccupied by tissue. Indeed, in the section represented by fig. 6 it is evident that if the more central elements were freed from contraction and restored to their original form and dimensions they would suffice to completely fill up the area in question.

* D. T. Gwynne-Vaughan, "On the Real Nature of the Tracheæ in the Ferns," *Ann. Bot.*, vol. xxiii. (No. 87), pp. 517–523, Pl. xxviii., 1908.

As regards the peripheral tissues of the stele, there is a stout "xylem sheath" of some six to eight layers of parenchyma (figs. 6 and 8, *xy. sh.*). This is succeeded by a wide belt of phloem consisting of four to six layers of large and conspicuous sieve-tubes without any intervening phloem parenchyma (figs. 6 and 8, *ph.*). On the outside of the phloem the tissues are less well preserved, but they are sufficiently clear to demonstrate the complete absence both of a protophloem and of the porose layers that characterise the recent *Osmundaceæ*. The absence of the protophloem is rendered all the more sure since this tissue is distinctly recognisable in the free leaf-traces, as will be shown later on. The pericycle abuts directly on the large sieve-tubes, and is about five layers thick (figs. 6 and 8, *per.*). It is well delimited from the cortex by a dark band of broken-up cells, which no doubt represent the remains of the lignified walls of the endodermis. It probably consisted of a single layer of cells, although at some points two layers of cells seem to have been endodermal in character (figs. 6 and 8, *en.*).

The inner cortex consists of ordinary thin-walled parenchyma, and is very poorly preserved. The outer cortex, on the other hand, is heavily sclerotic, and in transverse section its elements appear as very thick-walled cells with rounded lumens (fig. 14). They are not, however, fibrous, but in longitudinal section are seen to be short and oblong with bluntly rounded ends not more than four or five times as long as broad (fig. 15).

## The Departure of the Leaf-trace.

The leaf-trace departs in a typically protostelic manner, precisely as that of *Zalesskya gracilis.** It is therefore unnecessary for us to redescribe the process here, the departure being sufficiently illustrated by the figures 16 and 17 on Pl. III. While still within the endodermis of the stem the xylem strand of the leaf-trace is shortly oblong with rounded ends, and it contains a single deeply immersed almost central strand of protoxylem (fig. 18). It retains the same form for some time even after the leaf-trace has become free from the stem stele (fig. 19), and then it gradually becomes more or less elliptic as it passes outwards. At about this stage some of the centripetal tracheæ in front of the protoxylem strand on the adaxial side cease to occur, and are replaced by thin-walled parenchymatous cells (fig. 20). To put it in another way, these tracheæ are not succeeded above by other tracheæ but by parenchyma. In fact, the xylem stops short at this point, and as a result a small isolated island of parenchyma is now found on the adaxial side some little distance in front of the actual protoxylem group (fig. 21). As the leaf-trace passes out this island gradually enlarges (fig. 22) until at length even the most adaxial tracheæ stop short and the island becomes converted into a bay open on the adaxial side (fig. 23). The disappearing centripetal tracheæ do not all stop short at the same time, but some are continued upwards beyond the rest as isolated elements in the parenchyma of the bay (fig. 24). This bay then gradually becomes more and more open, and at the same time the leaf-

* Part II., p. 225.

trace as a whole becomes wider. While these changes are going on the single protoxylem group spreads itself out over the inner margin of the island or of the bay (figs. 22 and 24) and eventually divides into two separate groups (figs. 25–27). The actual division is usually delayed until the island has opened out into a bay, although it may take place before this happens. A few of the centripetal tracheæ immediately in contact with the actual protoxylem elements may still persist even after the bay has opened out, but these soon disappear and the protoxylems become truly endarch (fig. 28). After this stage is reached the xylem strand of the leaf-trace gradually takes up the form of a low arch with slightly incurved ends (fig. 29), and the protoxylems divide again until four or five distinct groups are found projecting from the adaxial concavity of the arch (figs. 28 and 29). All these changes take place while the leaf-trace is still in the inner cortex and its outline as a whole is still oblong or elliptic. Just as it is about to enter the sclerotic outer cortex the endodermis and ground-tissue invades the concavity of the bay and the trace becomes reniform (fig. 29). Once in the sclerotic cortex it rapidly takes up the horseshoe-shape outline characteristic of the *Osmundaceæ*, and the protoxylems increase to ten or more (fig. 1).

The great majority of the leaf-traces conform exactly with the above description. Three traces, however, were found in which the single protoxylem group was markedly excentric in position (figs. 30 and 31); this, however, seems to be of no particular importance, and the traces opened out in the usual way (fig. 32). A much more interesting variation was exhibited by four other traces, which may lead to conclusions of some importance. In these the single mesarch protoxylem had divided into two separate and distinct groups before any parenchyma whatever had appeared in the xylem of the trace (figs. 33–35). Indeed, in one case the protoxylem was already double before the xylem of the leaf-trace was yet free from the endodermis of the stem stele (fig. 35). The other cases occurred in traces that were well out in the inner cortex. The two protoxylem groups may have arisen by the early division of a single protoxylem, or they may run down independently into the xylem of the stem. Our specimens give no means of settling this point, nor do they give any information as to the behaviour of these leaf-traces in their further course out into the petiole.

## The Structure of the Petiole.

The leaf-trace is accompanied out through the sclerotic cortex of the stem by a sheath of thin-walled parenchyma which has mostly become decayed (fig. 36, *i. par.*) with the exception of a number of cells forming an irregular and much interrupted zone in close proximity to the trace (figs. 36 and 38, *res. l.*). These cells only differ from the rest of the parenchyma by their more resistant walls and by the amount of black carbonaceous matter they contain, indicating that they possessed dense and specialised contents. Similar elements also surround the leaf-trace while it is still in the inner cortex (fig. 1). In this region, at any rate, they are not sclerotic, although they may become so in the

outer petioles. This is the more probable since their position is occupied by normal sclerenchyma in the free petioles of certain other *Osmundaceæ*. It may here be remarked that an interrupted sheath of precisely similar cells occurs around the leaf-traces in the inner cortex of *Zalesskya diploxylon*—a point that was inadvertently omitted in our previous description of this plant.

In the coating of leaf-bases outside the sclerotic cortex of the stem, each petiole possessed a ring of homogeneous sclerenchyma enclosing the thin-walled ground-tissue mentioned above (figs. 1 and 36, *scl.*). There is also a certain amount of thin-walled parenchyma on the outside of this sclerotic ring (fig. 36, *o. par.*), which is prolonged on each side to form stout and broad stipular wings, the closely adpressed petioles being delimited from one another by delicate brown lines (figs. 1 and 36, *pet. l.*). None of our petioles were sufficiently far out to furnish reliable information as to the typical arrangement of the sclerenchyma in the stipular base. There are, however, indications of isolated sclerotic strands in the parenchyma of the stipules; and it is also possible that the free margins of the stipules were sclerotic, for the tissue in these regions differs in appearance from the general parenchyma. These points, so far as can be ascertained, are illustrated by the text figure 1.

DIAGRAM 1.—Diagrammatic restoration of a transverse section of an outer petiolar base of *Thamnopteris Schlechtendalii* to show the arrangement of the sclerenchyma.

As regards the leaf-trace itself, the adaxial ends of the horse-shoe become deeply incurved and almost hooked in the outermost petioles (fig. 1), and as many as twenty protoxylems may be counted along the adaxial margin of the xylem strand. The protoxylem elements of the leaf-trace when still in the xylem of the stem, and also for some distance out through the cortex, are simply scalariform. Farther out, however, in the free petiole they may consist of annular and spiral elements, but we possess no longitudinal sections of this region to determine the point. The xylem-sheath of the inmost traces is stout and conspicuous, but in the outer ones it becomes reduced to a single layer. The phloem is very distinct and completely surrounds the xylem. It is especially plentiful in the median region on both the abaxial and the adaxial surfaces of the inner traces (fig. 26, *ph.*), becoming more evenly distributed in the outer. The protophloem also is clearly visible all round the trace as a narrow dark band (fig. 26, *pr.ph.*), and at certain points in the inner traces its small constituent elements can be distinguished. The pericycle consists of about four layers of cells, and the whole

trace is surrounded by a well-defined endodermis, for the most part recognisable as a single layer of cells (figs. 26 and 37, *en.*).

Perhaps the most striking and interesting feature of the petiole is the presence in the pericycle of secretory sacs, which no doubt represent the mucilage sacs that occur in the same tissue in the living *Osmundaceæ*. In the fossil these elements are large vesicular cells, elongated in longitudinal section, and filled with black contents. Large numbers of them are present in the pericycle on both sides of the trace (figs. 36, 37, and 38, *S. s.*). On the abaxial side, however, they are confined to the median region, and in this *Thamnopteris* differs from the living *Osmundaceæ*, where the abaxial mucilage sacs form two dorso-lateral groups. In the living *Osmundaceæ* these sacs do not appear at all until near the top of the stipular region of the leaf-base, but in *Thamnopteris* they are already present by the time that the trace is in the sclerotic cortex of the stem (fig. 29).

### The Structure of the Roots.

The xylem strands of the roots are inserted upon those of the leaf-traces, but they vary considerably as regards the point of their insertion. They arise singly or in pairs, sometimes from the back of the leaf-trace xylem before the latter is yet free from the xylem of the stem (figs. 7, 16, 17, and 30), sometimes from the free leaf-trace in the inner cortex. No roots, however, were seen to arise from the leaf-traces once the parenchyma bay has been formed in the xylem. In the free leaf-trace the roots arise from the back or from the sides of the xylem, and in the latter case from the abaxial or even from the adaxial corner (fig. 39). The roots obtain a cortex of their own as they enter the sclerotic cortex of the stem. The root cortex consists of an inner thin-walled and an outer sclerotic zone, which remains still thick-walled even in the outermost regions of our sections. They bore their way in all directions through the stipular tissues of the petiolar coating, but they never perforate the sclerotic rings (fig. 1, *r.*). They have the structure of a typical diarch fern root with a rather stout xylem strand, and without further description are sufficiently illustrated by fig. 40. The xylem elements bear multiseriate pits similar to those in the stem stele.

*Locality.*—Near Bjelebei, government of Orenburg, Russia.

*Horizon.*—Upper Permian, "grès cuivreux" (see $P_2$ of Geological Table, Part II., p. 219).

## Bathypteris, Eichwald.

1860. Eichwald, *Lethæa Rossica*, vol. i., p. 96.

## Bathypteris rhomboidea, Kutorga, sp.

(Pls. VI., VII.)

1844. *Tubicaulis rhomboidalis*, Kutorga (*pars*), *Verhandl. d. miner. Gesell. zu St Petersburg*, pl. i. fig. 6.
1860. *Bathypteris rhomboidea*, Eichwald, *Lethæa Rossica*, vol. i., p. 96, pl. iv. figs. 1 and 2.
1869. *Bathypteris rhomboidea*, Schimper, *Traité de paléont. végét.*, vol. i., p. 704.
1887. *Bathypteris rhomboidea*, Schmalhausen, "Die Pflanzenreste der Artinskischen und Permischen Ablagerungen im Osten des Europäischen Russlands," *Mém. du Comité géol.*, vol. ii. (No. 4), pp. 9 and 36, pl. iii. figs. 6 and 7.

The specimen from which our material was cut is shown at fig. 41, about a half natural size, and is the same example as that figured by Eichwald in his *Lethæa Rossica*, pl. iv. figs. 1 and 2. The fossil does not contain the whole stem of the plant, but merely consists of a certain thickness of its outer coating of petiolar bases together with a small portion of the outer region of its cortex. The fragment we received was cut from the lower end of the specimen, and proved to be very imperfectly preserved; much of the mineral matter with which it has been infiltrated has been subsequently removed, leaving a petrifaction that is now somewhat fragile and friable. This rendered the preparation of satisfactory microscopical sections an extremely difficult matter, but thanks to the great skill of Dr F. Krantz sections have been prepared sufficiently intact to enable us to elucidate the chief structural points of the fossil.

In transverse sections of our material it is seen that the extreme inner margin of the fossil includes a certain amount of the outer sclerotic cortex of the stem represented by fragments of comparatively small-celled dark-coloured sclerenchyma, but it is so much broken up and disintegrated that little can be said about the structure of this region. In fact, the first tissues that are sufficiently intact to be serviceable for detailed description are those of the free petioles. One of the chief characters of the fossil is the looseness with which the petioles that form the coating to the stem are packed together (fig. 42). They are not in any way concrescent or even closely adpressed as in the previously described fossils, but they are quite free from one another, with clearly defined intervening spaces.

Another important feature of the petiolar bases of *Bathypteris* which distinguishes it from all the other *Osmundaceæ* known to us is the fact that they are entirely devoid of any stipular expansions. The transverse sections of the petioles are in fact simply rhomboidal in outline, fitting into one another without being closely adpressed.

All the leaf-traces present the typical horseshoe-shaped curve characteristic of the *Osmundaceæ*, but the arrangement of the sclerenchyma in the petiole varies consider-

ably according to the level at which the section is taken. In the outermost petioles (fig. 43, *int. scl.*) the leaf-trace is immediately surrounded by a broad zone of dense sclerenchyma. Then comes a wide belt of thin-walled tissue (fig. 43, *i. par.*), and then the customary petiolar sclerotic ring, which is here comparatively narrow (*sc. l.*). The sclerotic ring is in turn enveloped by several layers of thin-walled parenchyma, which maintain the rhomboidal outline of the sclerotic ring and are not prolonged at the sides into stipules. A peculiarly interesting feature of the petioles of *Bathypteris* is the presence of numerous slender spine-like outgrowths from their periphery, which project upwards into the spaces between the petioles and attain a considerable length. In petioles nearer the stem the inner sclerotic tissue in contact with the leaf-trace increases greatly in amount until it entirely fills up the concavity of the trace (fig. 44) and replaces almost completely the parenchyma lying between it and the sclerotic ring (fig. 45). This internal sclerenchyma follows the leaf-trace right into the stem undiminished in quantity, and is here separated from the outer sclerotic cortex of the stem only by a very few layers of parenchyma.

The constituent elements of the sclerenchyma differ considerably in the nature of their preservation. Those of the petiolar sclerotic rings are mostly well preserved, with almost homogeneous brown walls. So also are some of those of the inner sclerenchyma in contact with the leaf-trace; the walls of these elements being exceptionally thick and more or less distinctly stratified. In most of them, however, the layers of stratification have become separated as though they had been macerated, and the thickness of the wall is occupied by a number of narrow black concentric lamellæ alternating with broader and lighter-coloured bands (figs. 46 and 47). The lumen is almost obliterated, and is frequently filled by a small dark mass. In transverse section they have a rounded outline with small triangular intercellular spaces at the corners, while in longitudinal section they are shortly rectangular and blunt ended. The elements of the outer sclerotic rings are narrower and fibrous, and they also have small intercellular spaces at the angles.

As already stated, the periphery of the petiole is beset on all sides by spinose emergences which grow upwards parallel to the petioles in the spaces that lie between them. In a transverse section of the petiolar coating these spaces are almost completely filled up by the transverse sections of the numerous spines. The best preserved of these show that the centre of the spine is occupied by a stout strand of narrow cells with thick and usually lamellated cell-walls, which are surrounded by two or three layers of larger thin-walled cells (figs. 49 and 50). In longitudinal section the sclerotic cells are seen to be fibrous, while their thin-walled envelope is parenchymatous (fig. 52). In most of the spines, however, the more delicate outer layers have become decayed or worn away, and the sclerotic core alone is left (figs. 49 and 51); and in many of them the central elements even of the sclerotic core have disintegrated, leaving a small black mass of carbonaceous matter or simply an empty space (fig. 51). On account of the great variation in size of the transverse sections of the spines it would seem that

they tapered to fine points; at the same time they differ considerably in size even at the point of their insertion on the petiole. The thin-walled tissue of the spine is continuous at the base with the peripheral parenchyma of the petiole (fig. 50), into which the sclerotic core is also decurrent as a definite strand of fibres (fig. 48, *scl.*[1]), which may be traced downwards for a considerable distance, gradually approaching the sclerotic ring of the petiole, with which it eventually becomes completely confluent.

DIAGRAM 2.—Diagrammatic restoration of a transverse section of an outer petiolar base of *Bathypteris rhomboidea* to show the arrangement of the sclerenchyma.

The leaf-trace in the outer petioles is typically horse-shoe shaped. The xylem strand has numerous endarch protoxylems, the elements of which are probably annular or spiral or perhaps both, while those of the metaxylem are multiseriate. The endodermis abuts directly on the internal sheath of sclerenchyma, and at many points has conspicuously dark radial walls. The cells of the pericycle when preserved appear to have possessed somewhat dense contents (fig. 53). The phloem is very poorly preserved, being represented merely by a dark line indicating its crushed and collapsed elements. The xylem sheath, on the other hand, presents a feature of peculiar and unique interest. A large number of its cells are vertically elongated, and possess very dark and lamellated walls similar to those described in the cortical sclerenchyma (figs. 53 and 54, *xy. sh. scl.*). It is believed that these elements were actually sclerotic; and if this is so we know of no perfect parallel in the *Filicales*, the nearest analogy being found in *Adiantum trapeziforme*, var. *Funckii*, where the xylem parenchyma becomes thick-walled and fibrous. In *Bathypteris* the sclerotic elements of the xylem-sheath are more plentiful in the outer leaf-traces, and especially on the adaxial surface, where they may occupy almost the whole of its extent (fig. 53).

## THE ROOT.

A large number of roots run outwards in the interstices between the petioles, and branch frequently as they pass out. The majority of them possess a diarch xylem strand, but a considerable number of triarch roots were also met with (fig. 56). The

xylem strand is usually very stout, as shown in fig. 55, which may be regarded as a diarch root, although there are strong indications of a third protoxylem. In fact, it is probable that both types of structure occur at different points in the same root. In other roots the diarch xylem strand is very much thinner, and these are probably lateral branches. The cortex of the root is entirely sclerotic, the size of the cells increasing somewhat from the endodermis outwards.

*Locality.*—Mine Kloutschewsk, district of Bjelebei, government of Orenburg, Russia.

*Horizon.*—Upper Permian, "grès cuivreux" (*cf.* $P_2$ of Geological Table, Part II., p. 219).

## **Anomorrhœa**, Eichwald.

1860. EICHWALD, *Lethæa Rossica*, vol. i., p. 102.

## **Anomorrhœa Fischeri**, Eichwald.

(Pl. VIII.)

1860. *Anomorrhœa Fischeri*, Eichwald, *Lethæa Rossica*, vol. i., p. 102, pl. iv. figs. 3 and 4.
1869. *Anomorrhœa Fischeri*, Schimper, *Traité d. paléont. végét.*, vol. i., p. 702.

The original specimen of *Anomorrhœa Fischeri* was figured by EICHWALD in his *Lethæa Rossica*, pl. iv. figs. 3 and 4, and is again represented about natural size in Pl. VIII. fig. 57 of the present paper. The fossil consists only of a certain thickness of the coating of petiole bases that originally surrounded the stem, to which small fragments of the outer cortex are still adhering at some points. The outer surface of the fossil shows the obliquely fractured ends of the almost vertically growing petioles in the form of closely packed elongated rhomboidal scars.

In some of the transverse sections of our material, which was cut from the upper end of the type specimen, closely packed petiole bases alone are to be seen (fig. 58). In others the structure of the inmost leaf-traces is such that they must have been situated in the cortex of the stem (fig. 59, *C.*). Most of the tissues of this cortex have entirely disappeared, but no doubt it consisted almost entirely of the inner parenchymatous zone. It appears, therefore, that in this stem the outer sclerotic cortex is practically absent, being reduced to a narrow zone consisting merely of the confluent sclerotic rings of the petioles. Only the xylem strand of the leaf-trace is preserved in the inner cortex, and in longitudinal section it is seen to consist of tracheæ with the usual multiseriate pitting. In the inmost traces the xylem strand is only slightly curved, and it possesses a single median endarch protoxylem strand (fig. 60). In those farther out the protoxylem divides into two (fig. 61), subsequently into three (fig. 62), and at the same time the curve of the xylem strand gradually increases until, when it enters the free petiole, it has taken up the form of an arch (fig. 63). In the outer region of the cortex the leaf-traces are sometimes accompanied by a few sclerotic elements. In

the free petiole the leaf-trace as a whole assumes the characteristic shape of a horse-shoe. The softer tissues of the trace are very imperfectly preserved, but at some points the xylem sheath and even the sieve-tubes of the phloem could be made out on both sides of the xylem (figs. 64 and 65, *ph.*). The sclerotic ring of the petiole is well developed, and is surrounded by a narrow zone of parenchyma which is prolonged at

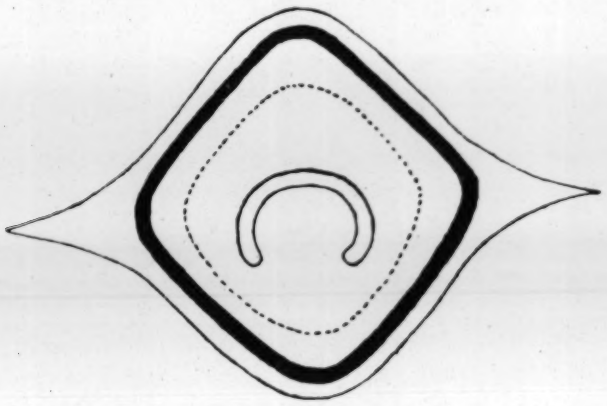


DIAGRAM 3.—Diagrammatic restoration of a transverse section of an outer petiolar base of *Anomorrhœa Fischeri* to show the arrangement of the sclerenchyma. The area within the dotted line probably becomes sclerotic at a point farther out in the petiole.

the sides into very short stipular wings (text fig. 3). Our outermost petioles were too close in to show the full development of the stipules or the typical arrangement of the sclerenchyma. The tissue on the inside of the sclerotic ring surrounding the leaf-trace, and included in the area outlined by the dotted line in text fig. 3, is distinctly thick walled, and farther out in the petiole may develop into sclerenchyma. No sclerenchyma was observed in the stipular wings of any of the petioles contained in our sections.

The roots were all of the normal diarch type, the only tissues preserved being the xylem strand and a sheath of dense sclerenchyma in immediate contact with the stele. This sclerotic sheath is already present while the root is still in the inner cortex of the stem, and is still maintained in the outermost parts of our sections.

*Locality.*—Copper mines of Kloutschewsk, district of Bjelebei, government of Orenbourg, Russia.

*Horizon.*—Upper Permian, "grès cuivreux" (*cf.* $P_2$ of the Geological Table, Part II., p. 219).

## GENERAL CONCLUSIONS.

In the discussion of the vascular anatomy of the *Osmundaceæ*, *Thamnopteris Schlechtendalii* occupies a position of special importance in that it verifies and expands a number of statements that could only be made with certain reservation as regards the Zalesskyas described in Part II. of this series. Of particular interest is the confirmation of the fact that the central elements of the xylem are really tracheal in

nature, and the additional evidence provided for the complete continuity of these tracheæ up to the very centre of the stele. In the face of these facts it seems to us almost impossible to avoid the conclusion that the pith of the *Osmundaceæ* has been derived directly from an originally solid xylem mass. This xylem, we believe, primitively consisted of normal elongated tracheæ throughout, and we regard *Zalesskya* and *Thamnopteris* as representing one of the stages passed through by the central tracheæ on their way to become short-celled medullary parenchyma. In large and solid masses of xylem the efficiency of the central elements as water-conductors seems in general to decrease the farther they are from the periphery; possibly owing to their increased distance from any of the living cells of the stele, so that the total elimination of this function in the most central elements would not be attended by any serious disadvantage to the water current. Again, from their central position these elements can render but little assistance towards the support of an erect stem, such as we believe these stems to have been (this may also be a reason why the primitive and mechanically inefficient porose and reticulate types of perforation are retained by the central tracheæ for a longer time than by the peripheral). It seems clear, therefore, that an economy would be effected if their walls were no longer thickened at all, and especially if they could be converted into some other kind of tissue with different and more useful functions. The exact manner in which the change was brought about has yet to be made clear. In *Thamnopteris*, however, there are distinct indications that the central tracheæ were originally arranged in vertical files, the end members of which are more or less pointed. This would suggest that the still meristematic central elements of the desmogen strand underwent septation during, or shortly after, their elongation.

In their further alteration into a parenchymatous pith the short central tracheæ of *Zalesskya* and *Thamnopteris* would have to completely lose their thickening, and in consequence their pitting. This may take place in two ways: either the tracheæ may all become transformed simultaneously, resulting directly in a homogeneous pith, or else some of the tracheæ may lose their tracheal characteristics before the rest, which would result first of all in the formation of a "mixed pith" of short tracheal elements scattered amongst parenchyma. If the latter were the course pursued, *Osmundaceæ* must have existed with a central stelar tissue very similar to that which occupies the axis of the stele of a Zygopterid stem. Indeed, if the transformation of the central xylem were to extend so far outwards as to reach the immersed protoxylems, a stelar structure almost exactly similar to that of *Zygopteris corrugata* would be attained.* If the steles of the *Osmundaceæ* and the *Zygopterideæ* have evolved along parallel lines from the solid xylemed stele of the common ancestor we have assumed for the two orders, the central tissue of the Zygopterid stele must be regarded as a mixed pith rather than as a mass of confluent diffuse protoxylems. Further, if the Zygopterid

* A comparison that has also been made by TANSLEY in his lectures on the evolution of the Filicinean vascular system, *New Phytologist*, vol. i., p. 260, 1907.

line of descent is at all close to the Osmundaceous, we must be prepared for the existence of a *Zygopteris* with a solid xylem like that of *Thamnopteris*, the central elements consisting entirely of short tracheæ without any parenchyma. Such a discovery, in fact, we hopefully anticipate.

To turn now to the mesarchy of the leaf-trace xylem in the neighbourhood of the stem stele. This point, which has already been described as of frequent occurrence in *Zalesskya gracilis*, becomes in *Thamnopteris* a perfectly regular and constant phenomenon. If it can be maintained that the structure of the leaf-trace in its course through the cortex of the stem may give some indication of the earlier stages in its phylogenetic development, this mesarchy becomes a matter of considerable interest. We have already discussed this subject in a short paper published in the *Proceedings* of this Society,* in which we endeavoured to establish the theory that the adaxially curved endarch xylem of the leaf-trace in the free petiole of the *Osmundaceæ* has been gradually evolved from a primitively mesarch strand through a series of changes that are briefly recapitulated by the leaf-trace xylem of *Thamnopteris* in its passage through the cortex (*cf.* Pl. IV.). We also regard it probable that a similar origin may be ascribed to all Filicinean traces that can be derived from the adaxially curved endarch type.

A peculiar and conspicuous feature of the leaf-trace of *Thamnopteris* is the appearance of mucilage sacs in the pericycle, which afford unexpected confirmation of its close relationship with the modern *Osmundaceæ*. As regards *Bathypteris* and *Anomorrhœa*, in spite of the absence of all knowledge of their stem structure, the close correspondence of the essential points in the structure of their petioles with those of the other *Osmundaceæ* practically ensures their inclusion in the order. Judging from the structure of the petiole only, *Bathypteris* is by far the most aberrant type. It is separated sharply from all the others, not only by the complete absence of stipules, but also by the presence of spinose emergences and by the occurrence of sclerotic elements in the xylem sheath. The unfortunate absence of the stem renders any speculation as to the primitive or specialised nature of these interesting features too hazardous to be pursued at present.†

Our thanks are especially due to Mons. Th. Tschernyschew for generously supplying us with materials for the examination of these classical fern stems, and also to Mons. Zalessky, through whom they were communicated to us, and for his many other kind offices.

* Gwynne-Vaughan and Kidston, "On the Origin of the Adaxially Curved Leaf-trace in the Filicales," *Proc. Roy. Soc. Edin.*, vol. xxviii., part vi. (No. 29), p. 433, 1908.

† Since the publication of the first part of these memoirs we have been able, through the great kindness of Prof. C. Eg. Bertrand, to examine a type specimen of *Grammatopteris Rigolloti*. The specimen exhibited only an opaque polished surface, and accurate conclusions as to its structure were difficult to arrive at. Still, the xylem strands of the leaf-traces in the cortex were almost straight oblong bands with small elements along the margins of their extremities. So far as we could make out, the general features of this fossil prohibit the especially close affinities with the *Osmundaceæ* that we previously suspected.

We have again to express our indebtedness to the Executive Committee of the Carnegie Trust for an additional grant to defray the cost of the plates necessary to illustrate this part.

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## DESCRIPTION OF FIGURES.

The figures are all from untouched photographs.

The following lettering is used throughout: *xy.*, xylem; *prx.*, protoxylem; *xy. sh.*, xylem sheath; *ph.*, phloem; *pr. ph.*, protophloem; *per.*, pericycle; *en.*, endodermis; *C.*, cortex; *l.t.*, leaf-trace; *r.*, root.

### Plate I.

Fig. 1. *Thamnopteris Schlechtendalii.* Transverse section of specimen. *o. xy.*, outer xylem ring; *c. xy.*, central xylem; *i. C.*, inner cortex; *sc. C.*, sclerotic outer cortex; *i. par.*, inner parenchyma of petiole; *o. par.*, outer parenchyma of petiole; *Scl.*, sclerotic ring of petiole; *r.*, root. × 2. (Slide 1279.)

### Plate II.

Fig. 2. *Thamnopteris Schlechtendalii.* Surface view of type specimen. (Photograph by Mons. R. Koch; forwarded by Mons. M. Zalessky.) Half nat. size.

Fig. 3. *Thamnopteris Schlechtendalii.* Surface view of the block investigated. About natural size.

Fig. 4. *Thamnopteris Schlechtendalii.* Another view of the same block showing impressions of roots, *r.* About nat. size.

Fig. 5 *a* and *b*. *Osmunda cinnamomea.* Branching root-systems dissected out from coating of petiole bases. Nat. size.

Fig. 6. *Thamnopteris Schlechtendalii.* Portion of stele in transverse section. × 13. (Slide 1281.)

Fig. 7. *Thamnopteris Schlechtendalii.* Longitudinal section of stele showing departure of a leaf-trace and of a root stele. × 7. (Slide 1285.)

Fig. 8. *Thamnopteris Schlechtendalii.* Transverse section of the peripheral tissues of the stele. × 50. (Slide 1281.)

### Plate III.

Fig. 9. *Thamnopteris Schlechtendalii.* Longitudinal section of a portion of the outer xylem ring. × 75. (Slide 1285.)

Fig. 10. *Thamnopteris Schlechtendalii.* Tracheæ of the outer xylem ring in longitudinal section to show the multiseriate pitting. × 200. (Slide 1285.)

Fig. 11. *Thamnopteris Schlechtendalii.* Portion of the central xylem in longitudinal section. Contrast with fig. 9. × 75. (Slide 1285.)

Figs. 12 and 13. *Thamnopteris Schlechtendalii.* Tracheæ of the central xylem in longitudinal section to show reticulate pitting. × 200. (Slide 1285.)

Fig. 14. *Thamnopteris Schlechtendalii.* Transverse section of a portion of the sclerotic cortex of the stem. × 150. (Slide 1281.)

Fig. 15. *Thamnopteris Schlechtendalii.* Longitudinal section of the same. × 150. (Slide 1285.)

Fig. 16. *Thamnopteris Schlechtendalii.* Transverse section of departing leaf-trace. × 15. (Slide 1281.)

Fig. 17. *Thamnopteris Schlechtendalii.* Transverse section of departing leaf-trace. Xylem almost free. × 15. (Slide 1281.)

PLATE IV.

Fig. 18. *Thamnopteris Schlechtendalii.* Departing leaf-trace xylem still within endodermis of stem stele. × 15. (Slide 1279.)

Fig. 19. *Thamnopteris Schlechtendalii.* Free leaf-trace in close proximity to stele. × 15. (Slide 1279.)

Fig. 20. *Thamnopteris Schlechtendalii.* Leaf-trace showing first appearance of parenchyma on adaxial side of the protoxylem. × 15. (Slide 1279.)

Fig. 21. *Thamnopteris Schlechtendalii.* Leaf-trace with small island of parenchyma. × 15. (Slide 1279.)

Fig. 22. *Thamnopteris Schlechtendalii.* Leaf-trace with large island of parenchyma. × 15. (Slide 1279.)

Fig. 23. *Thamnopteris Schlechtendalii.* Leaf-trace with the island of parenchyma just opening out to a bay. × 15. (Slide 1280.)

Fig. 24. *Thamnopteris Schlechtendalii.* Leaf-trace with open bay of parenchyma; protoxylem spreading out. × 15. (Slide 1280.)

Figs. 25, 26, and 27. *Thamnopteris Schlechtendalii.* Leaf-trace with two protoxylems. Note a few centripetal tracheæ in front of protoxylem in fig. 26. × 15. (Slides 1279 (figs. 26 and 27) and 1286.)

Fig. 28. *Thamnopteris Schlechtendalii.* Leaf-trace with several protoxylems. × 15. (Slide 1280.)

Fig. 29. *Thamnopteris Schlechtendalii.* Leaf-trace becoming reniform; *S. s.*, secretory sacs. × 15. (Slide 1280.)

PLATE V.

Fig. 30. *Thamnopteris Schlechtendalii.* Leaf-trace just departing; excentric protoxylem. × 15. (Slide 1279.)

Fig. 31. *Thamnopteris Schlechtendalii.* Free leaf-trace with excentric protoxylem. × 15. (Slide 1279.)

Fig. 32. *Thamnopteris Schlechtendalii.* Leaf-trace with bay of parenchyma in front of excentric protoxylem. × 15. (Slide 1280.)

Figs. 33, 34, and 35. *Thamnopteris Schlechtendalii.* Leaf-traces showing double mesarch protoxylems. × 22. (Figs. 33 and 35, slide 1279; fig. 34, slide 1280.)

Fig. 36. *Thamnopteris Schlechtendalii.* Transverse section of a portion of an outer petiole to show general tissues. *muc. s.*, mucilage sacs; *res. c.*, zone of resistant cells; *i. par.*, inner parenchyma; *o. par.*, outer parenchyma: *Scl.*, sclerotic ring; *pet. l.*, petiolar limit. × 15. (Slide 1282.)

Fig. 37. *Thamnopteris Schlechtendalii.* End of the leaf-trace under higher power. Lettering as in fig. 36. × 30. (Slide 1283.)

Fig. 38. *Thamnopteris Schlechtendalii.* Part of leaf-trace under still higher power to show mucilage sacs. Lettering as in fig. 36. × 55. (Slide 1282.)

Fig. 39. *Thamnopteris Schlechtendalii.* Transverse section of free leaf-trace showing two root steles arising from the adaxial corners. × 20. (Slide 1281.)

Fig. 40. *Thamnopteris Schlechtendalii.* Transverse section of a root in its passage through the leaf-coating. × 30. (Slide 1289.)

PLATE VI.

Fig. 41. *Bathypteris rhomboidea.* Surface view of the type specimen. (Photograph by Mons. R. Koch; forwarded by Mons. M. Zalessky.) Half nat. size.

Fig. 42. *Bathypteris rhomboidea.* Transverse section of specimen. × 2. (Slide 1292.)

Fig. 43. *Bathypteris rhomboidea.* Transverse section of an outer petiole. × 6. (Slide 1292.)

Fig. 44. *Bathypteris rhomboidea* Transverse section of a petiole closer in, showing increased amount of internal sclerenchyma. *int. sc.*, internal sclerenchyma; *i. par.*, internal parenchyma; *o. par.*, outer parenchyma. × 6. (Slide 1291.)

Fig. 45. *Bathypteris rhomboidea.* Transverse section of a petiole still closer in. *int. sc.*, internal sclerenchyma; *i. par.*, the inner parenchyma reduced to a narrow zone. × 7. (Slide 1292.)

Fig. 46. *Bathypteris rhomboidea.* Elements of internal sclerenchyma in transverse section showing usual preservation. × 110. (Slide 1291.)

Fig. 47. *Bathypteris rhomboidea.* Same elements showing different type of preservation. Observe the intercellular spaces. × 110. (Slide 1291.)

## Plate VII.

Fig. 48. *Bathypteris rhomboidea.* Transverse section of the peripheral tissues of a petiole showing insertion of the spinose emergences. *scl.*[1], sclerotic cores of the spines. × about 30. (Slide 1291.)

Figs. 49 and 50. *Bathypteris rhomboidea.* Transverse sections of spines showing the sclerotic core, *scl.*[1], surrounded by a parenchymatous sheath, *par. sh.* × 110 and × 70. (Slides 1292 and 1290.)

Fig. 51. *Bathypteris rhomboidea.* Transverse sections of free spines consisting of the sclerotic core alone. × 110. (Slide 1291.)

Fig. 52. *Bathypteris rhomboidea.* Longitudinal section of a spine with sclerotic core and parenchymatous sheath. *o. par.*, peripheral tissue of adjoining petioles. × 70. (Slide 1297.)

Fig. 53. *Bathypteris rhomboidea.* Transverse section of the end of a leaf-trace. *xy. sh. scl.*, sclerotic cells in the xylem sheath. × 55. (Slide 1292.)

Fig. 54. *Bathypteris rhomboidea.* Portion of transverse section of inner margin of a leaf-trace showing the sclerotic cells of the xylem sheath (*xy. sh. scl.*). × 200. (Slide 1292.)

Fig. 55. *Bathypteris rhomboidea.* Transverse section of a diarch root. × 33. (Slide 1295.)

Fig. 56. *Bathypteris rhomboidea.* Transverse section of a triarch root. × 33. (Slide 1292.)

## Plate VIII.

Fig. 57. *Anomorrhœa Fischeri.* Surface view of type specimen. (Photograph by Mons. R. Koch; forwarded by Mons. M. Zalessky.) Nat. size.

Fig. 58. *Anomorrhœa Fischeri.* A transverse section of specimen showing petioles only. × 3. (Slide 1298.)

Fig. 59. *Anomorrhœa Fischeri.* A transverse section showing a portion of the cortex of the stem attached to the petiolar coating, *Pet. sh.*; *C.*, cortex. × 3. (Slide 1304.)

Fig. 60. *Anomorrhœa Fischeri.* Transverse section of the leaf-trace xylem in the cortex; nearest the stele with one protoxylem. × 63. (Slide 1304.)

Fig. 61. *Anomorrhœa Fischeri.* Similar section farther out with two protoxylems. × 63. (Slide 1306.)

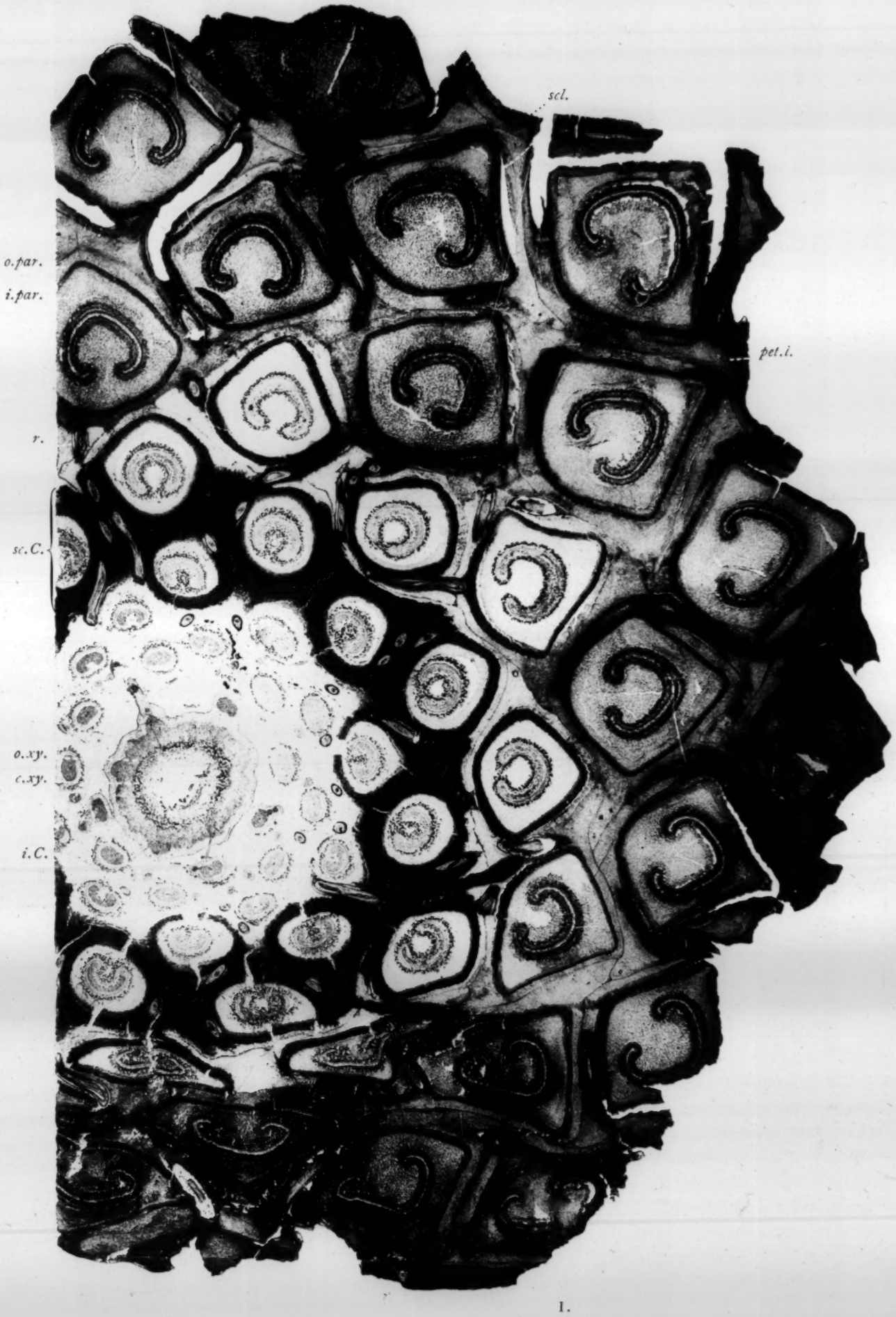
Fig. 62. *Anomorrhœa Fischeri.* Similar section still farther out with three protoxylems. × 63. (Slide 1305.)

Fig. 63. *Anomorrhœa Fischeri.* Transverse section of a free petiole. × 10. (Slide 1302.)

Figs. 64 and 65. *Anomorrhœa Fischeri.* Transverse sections of the ends of leaf-traces showing phloem. × 85. (Slides 1298 and 1303.)

Fig. 66. *Anomorrhœa Fischeri.* Transverse section of the end of a leaf-trace showing protoxylem strand. × 85. (Slide 1303.)

KIDSTON AND GWYNNE-VAUGHAN: FOSSIL OSMUNDACEÆ. PART III. PLATE I.

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*R. Kidston, Photomic.*

THAMNOPTERIS SCHLECHTENDALII. Eichwald sp.

KIDSTON AND GWYNNE-VAUGHAN: FOSSIL OSMUNDACEÆ. PLATE II.

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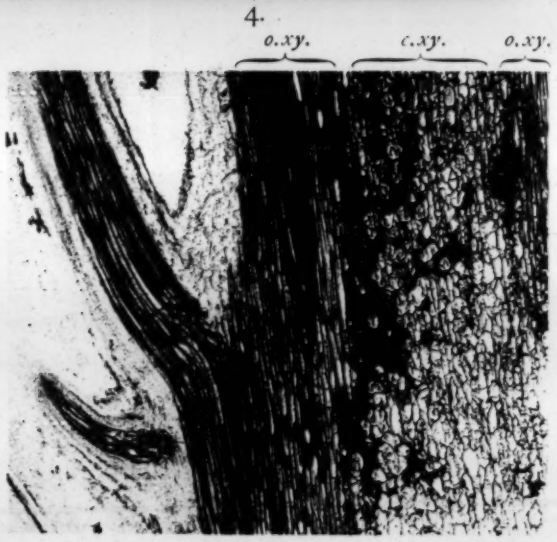


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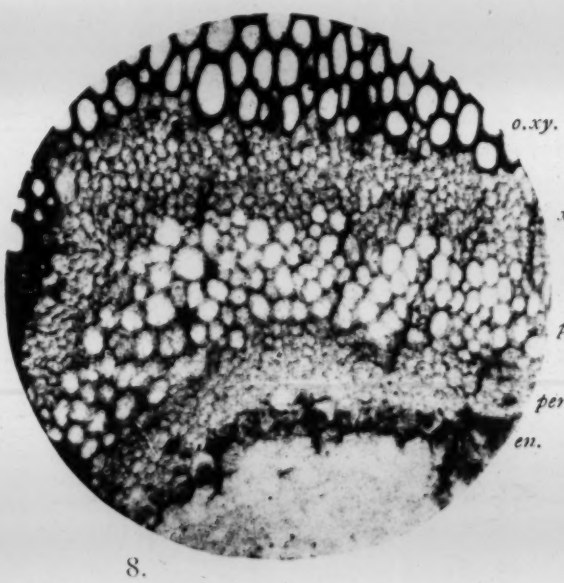


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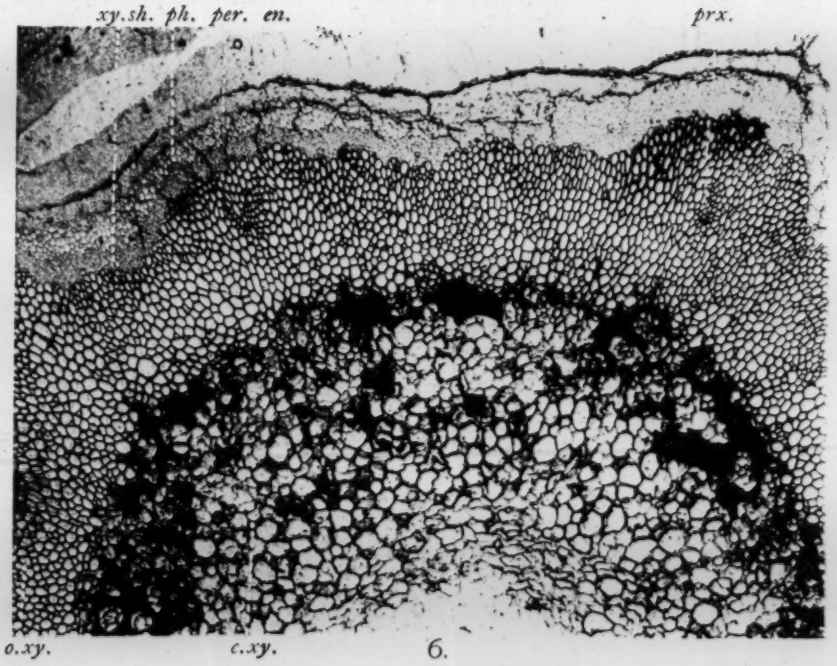


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*K. Kidston, Photomic.*

THAMNOPTERIS SCHLECHTENDALII. Eichwald sp.

KIDSTON AND GWYNNE-VAUGHAN: FOSSIL OSMUNDACEÆ. PLATE III.

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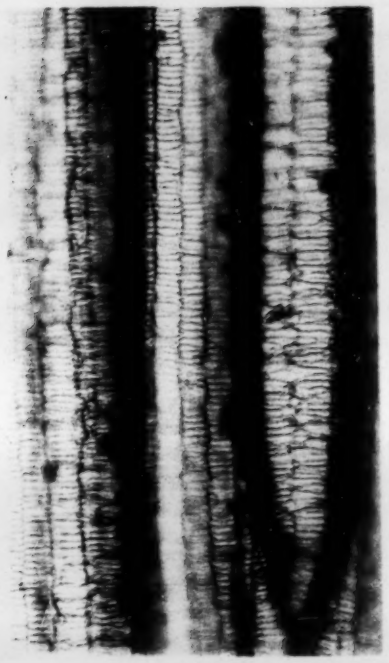

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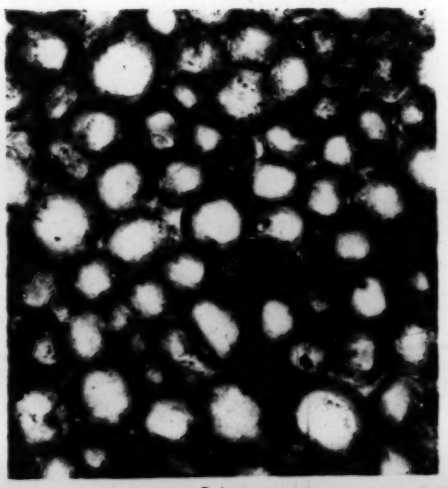

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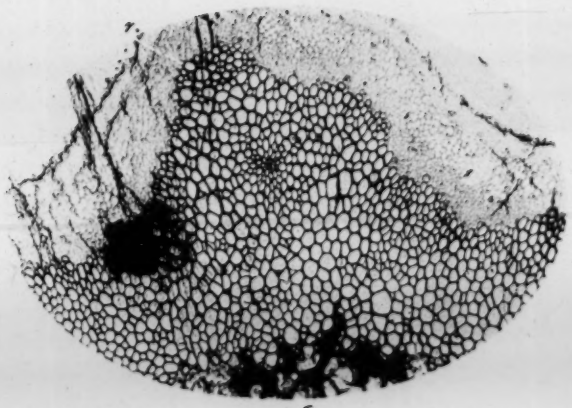

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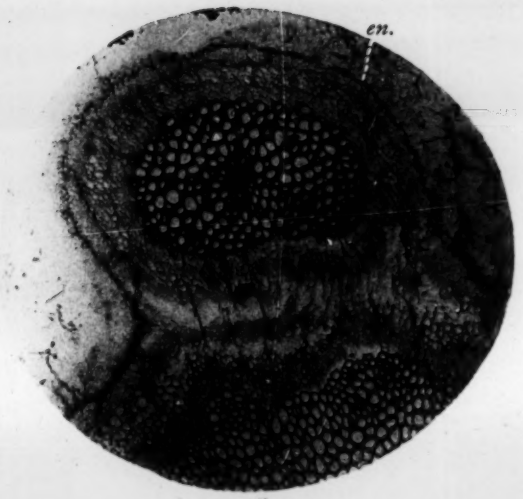
*R. Kidston, Photomic.*

THAMNOPTERIS SCHLECHTENDALII. Eichwald sp.

KIDSTON AND GWYNNE-VAUGHAN: FOSSIL OSMUNDACEÆ. PLATE IV.



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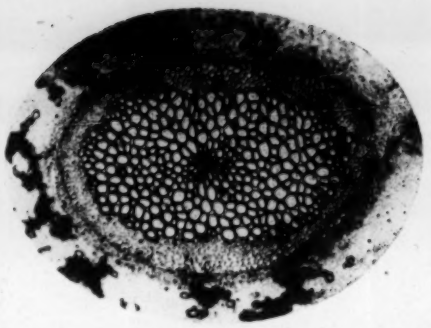
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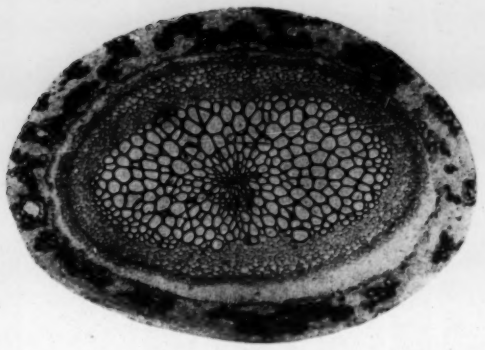
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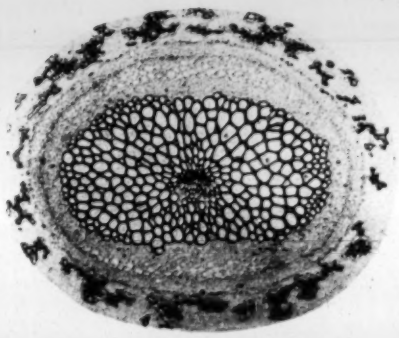
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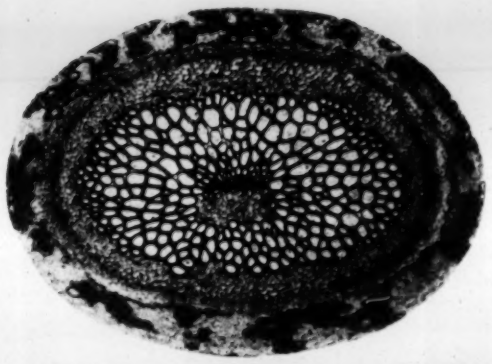
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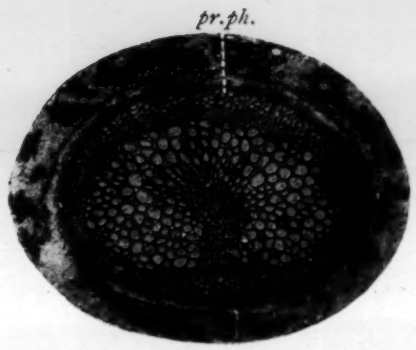

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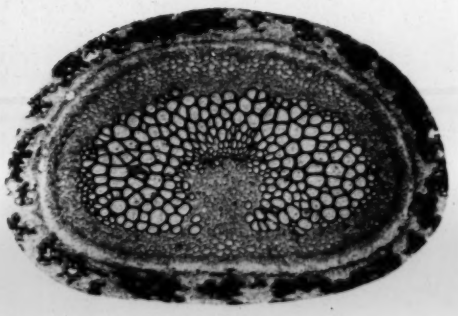
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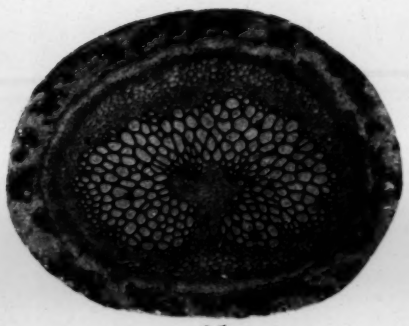
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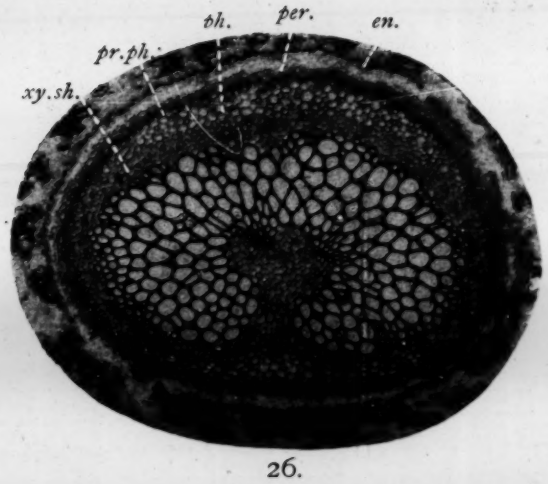

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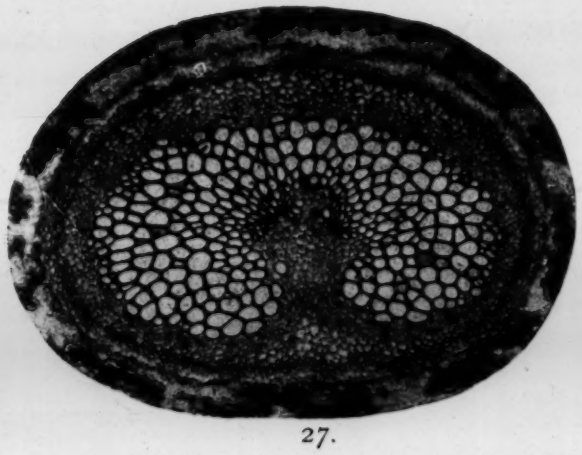
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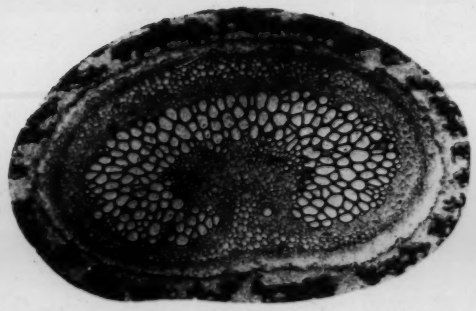
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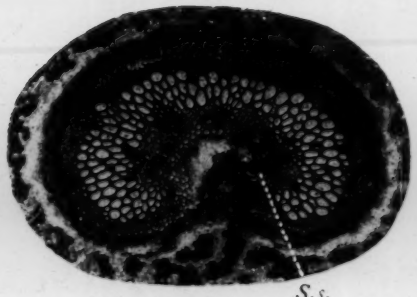

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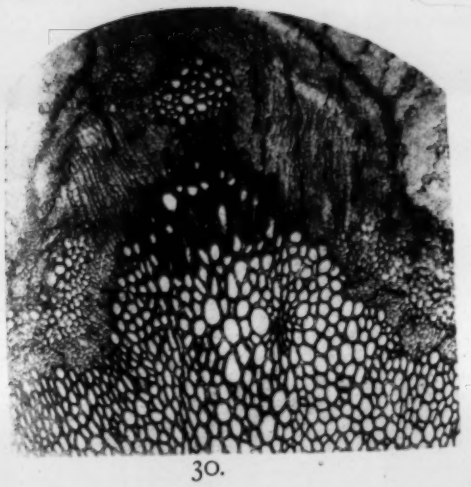
*R. Kidston, Photomic.*

THAMNOPTERIS SCHLECHTENDALII. Eichwald sp.

KIDSTON AND GWYNNE-VAUGHAN: FOSSIL OSMUNDACEÆ. PLATE V.



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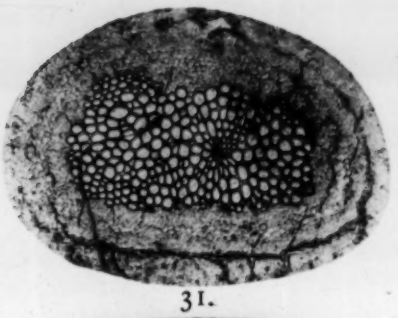

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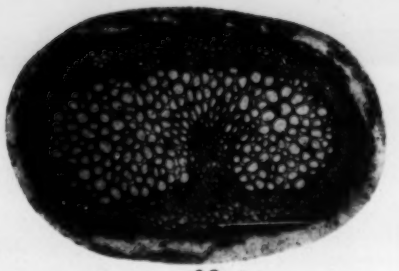

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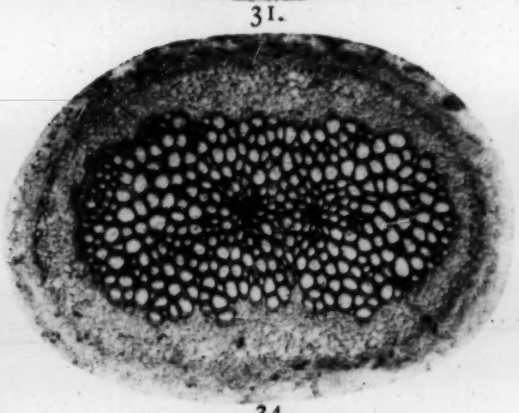

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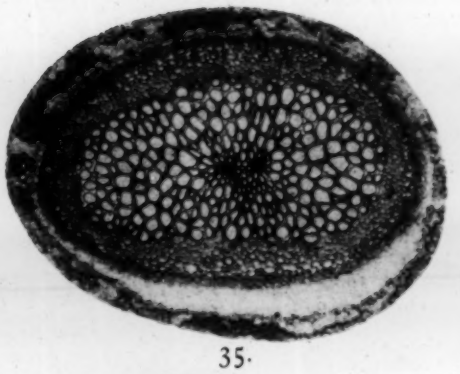

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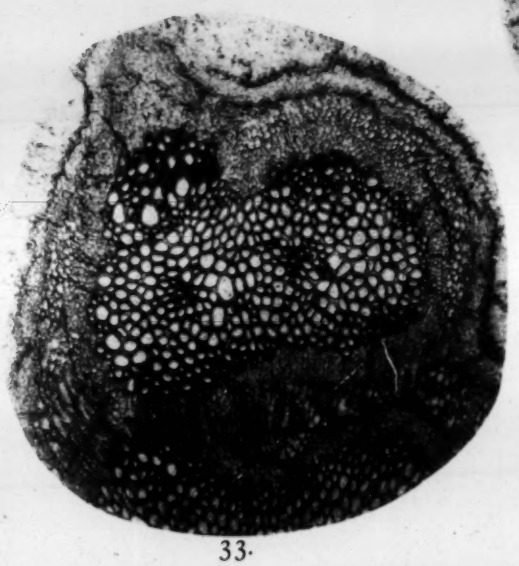

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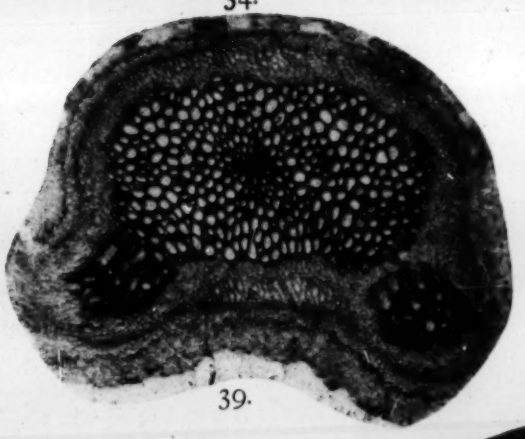

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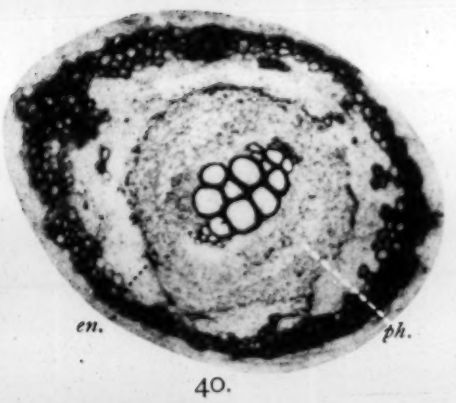


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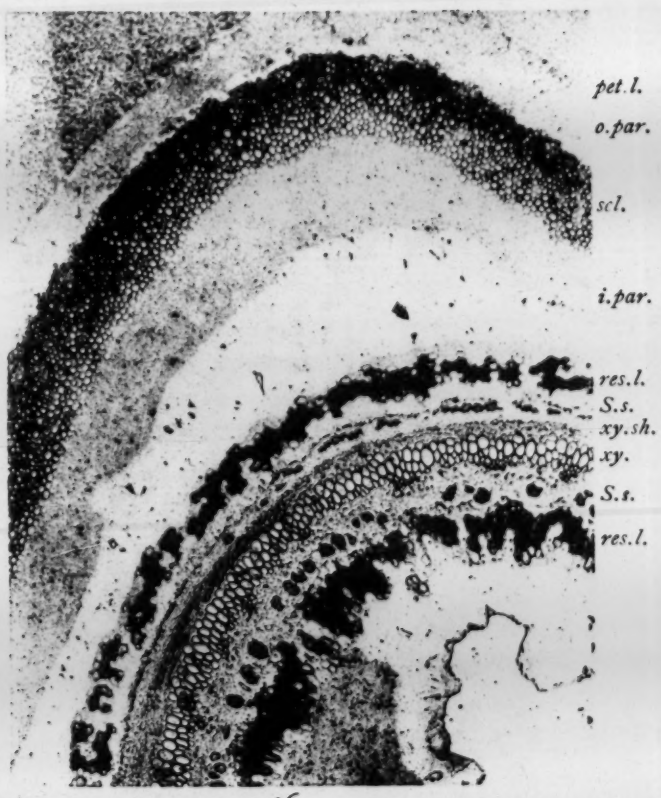


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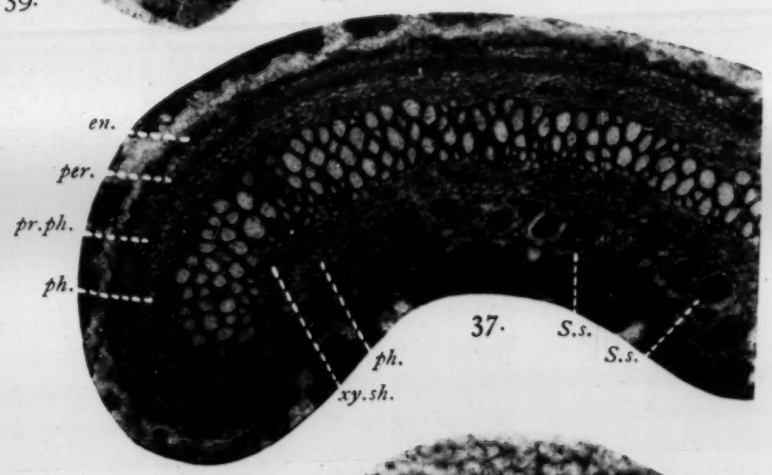


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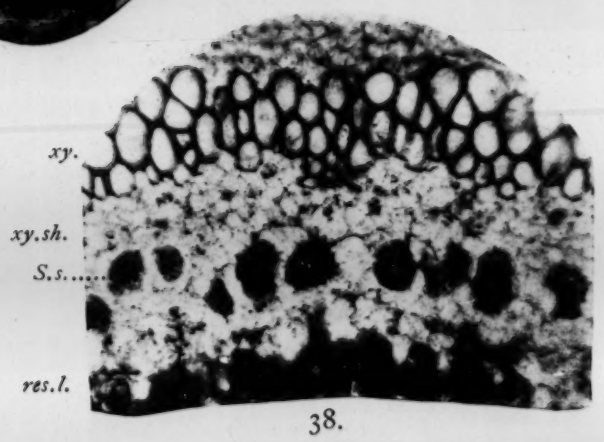


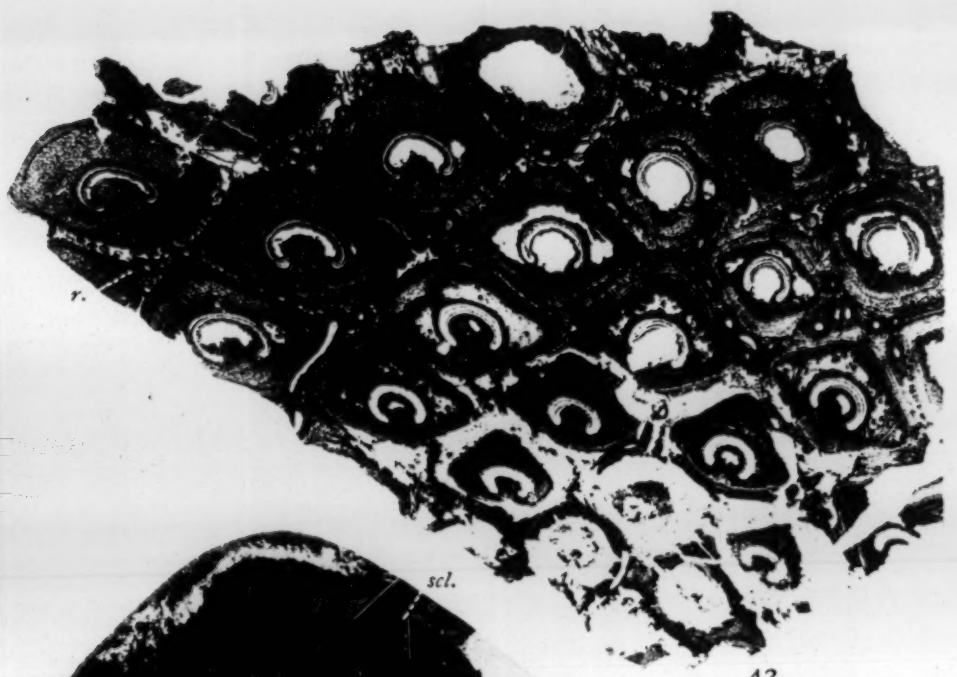

38.

*R. Kidston, Photomic.*

THAMNOPTERIS SCHLECHTENDALII. Eichwald sp.

KIDSTON AND GWYNNE-VAUGHAN: FOSSIL OSMUNDACEÆ. PLATE VI.

41.

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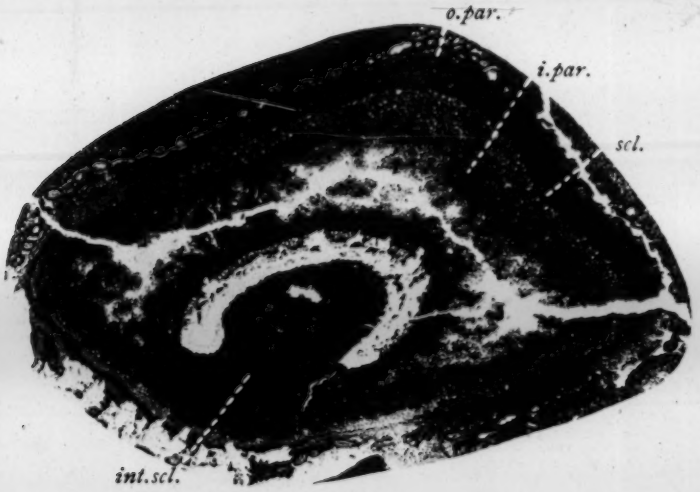


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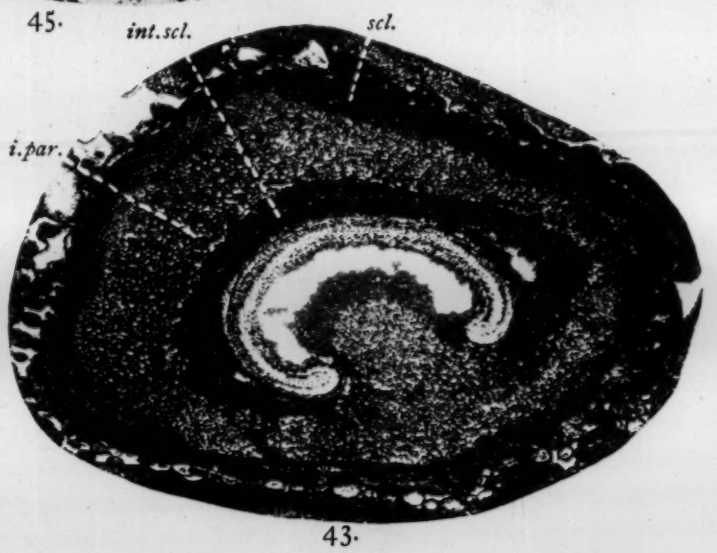


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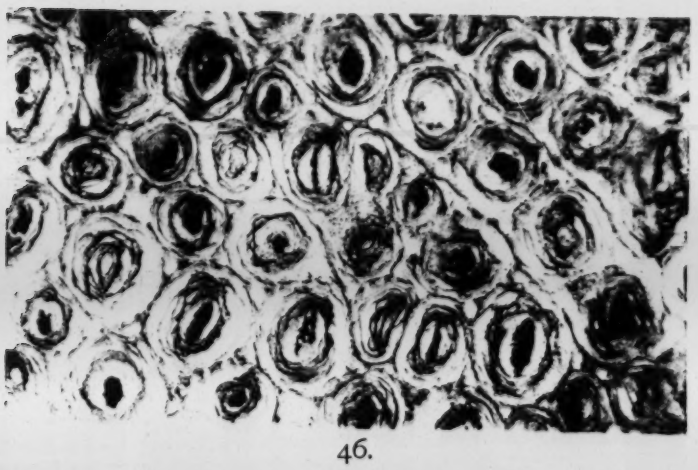


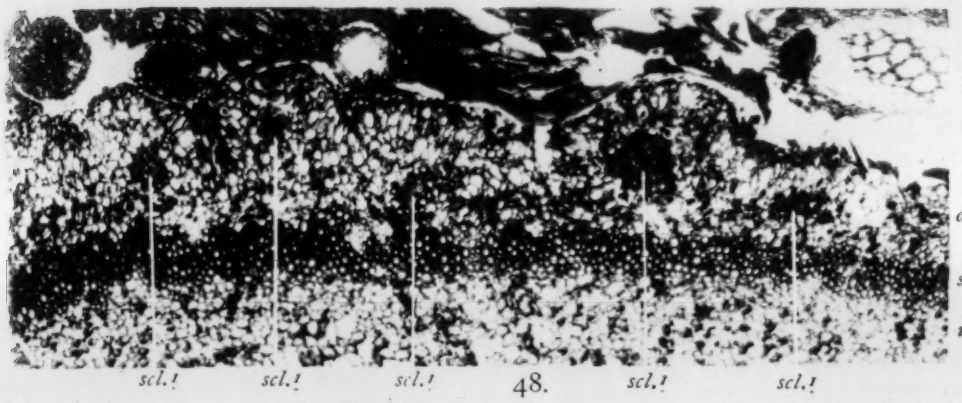
46.

47.

*R. Kidston, Photomic.*

BATHYPTERIS RHOMBOIDEA. Kutorga sp.

KIDSTON AND GWYNNE-VAUGHAN: FOSSIL OSMUNDACEÆ. PLATE VII.

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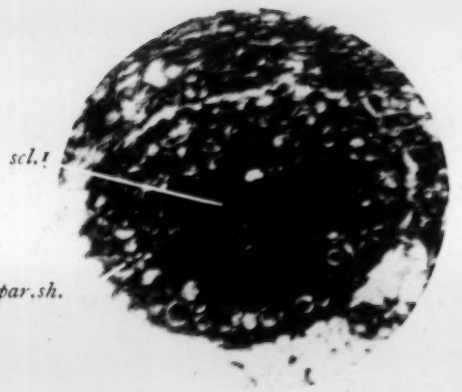


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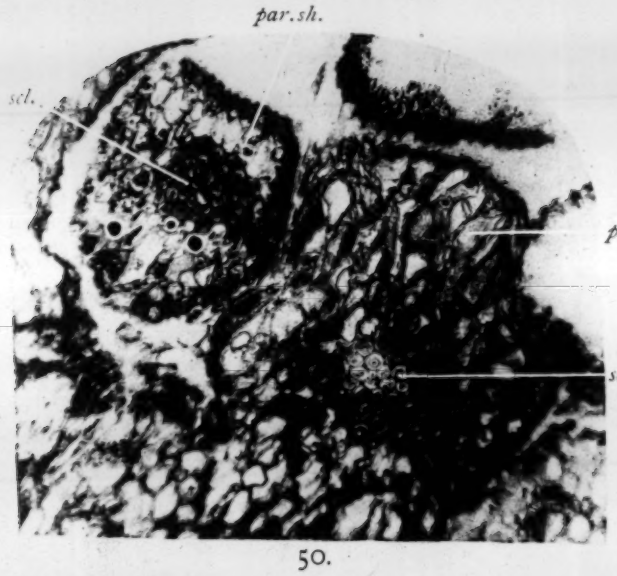


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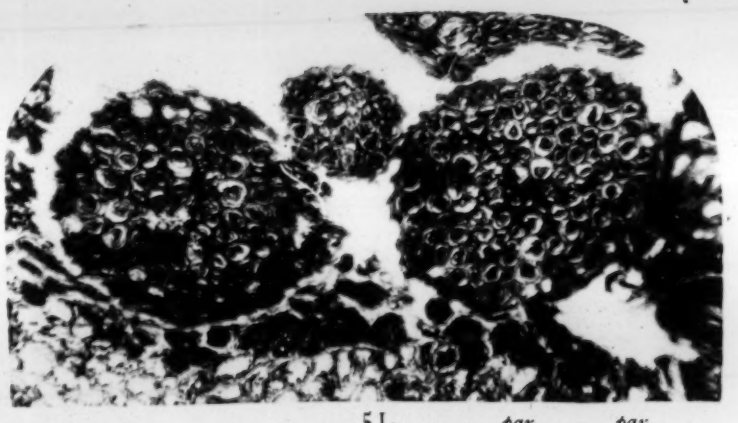

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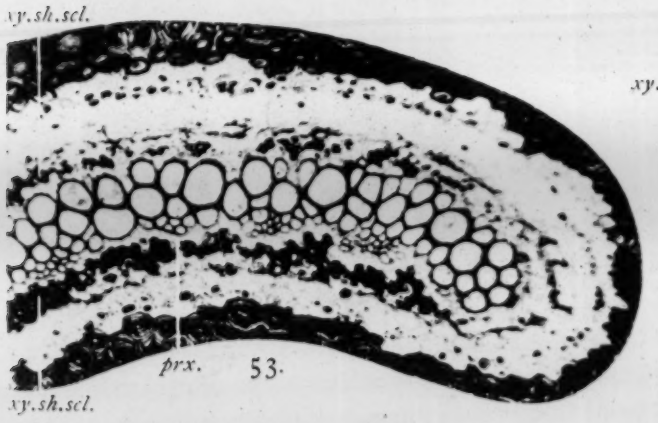


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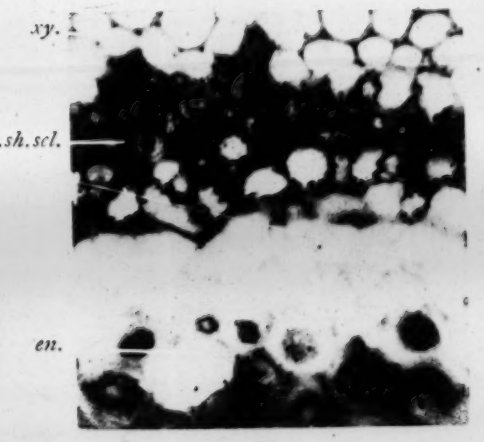


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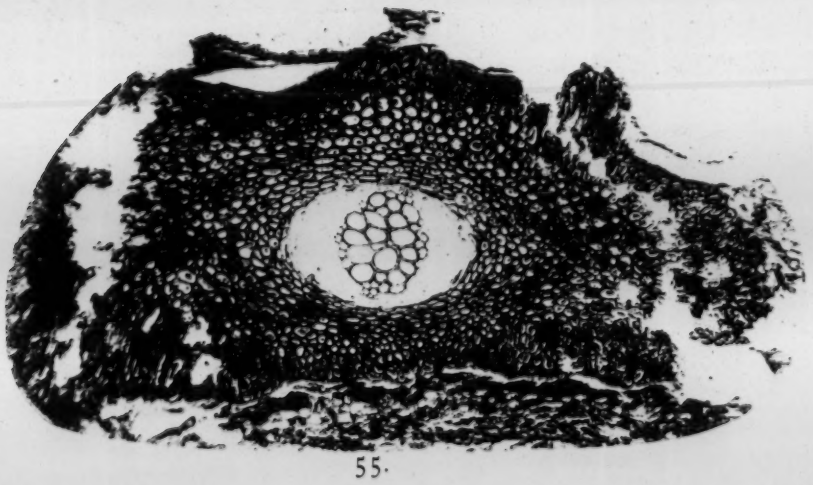

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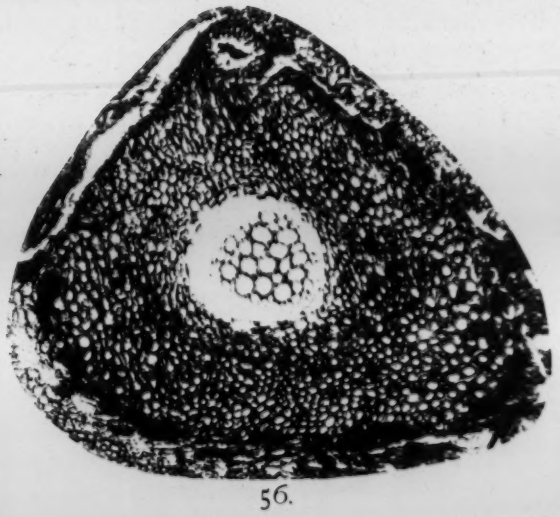


56.

R. Kidston, Photomic.

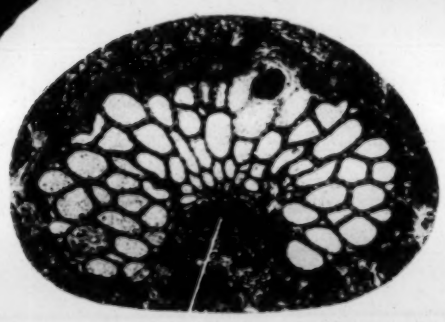
BATHYPTERIS RHOMBOIDEA. Kutorga sp.

KIDSTON AND GWYNNE-VAUGHAN: FOSSIL OSMUNDACEÆ. PLATE VIII.

57.

58.

59.

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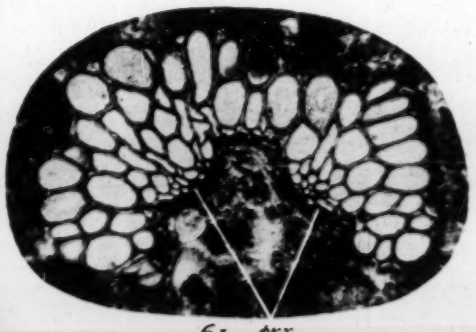


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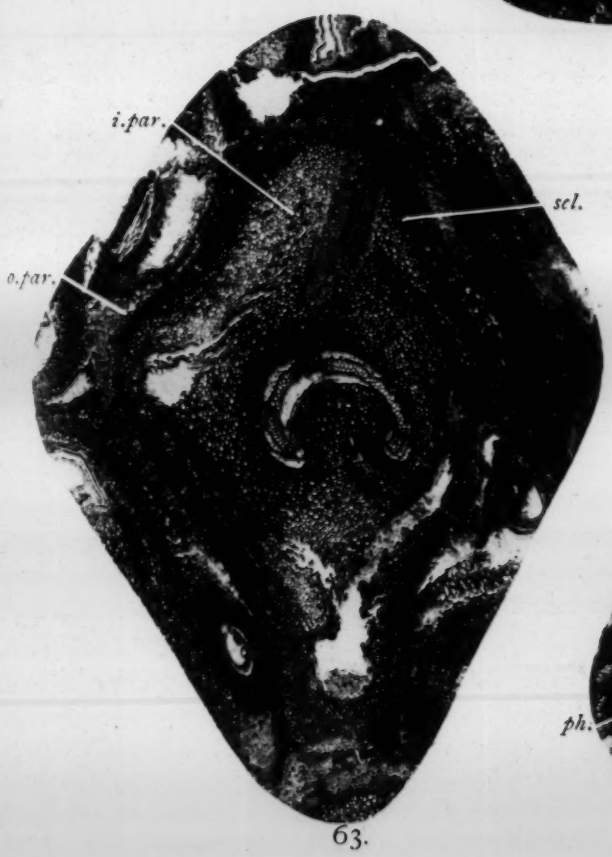


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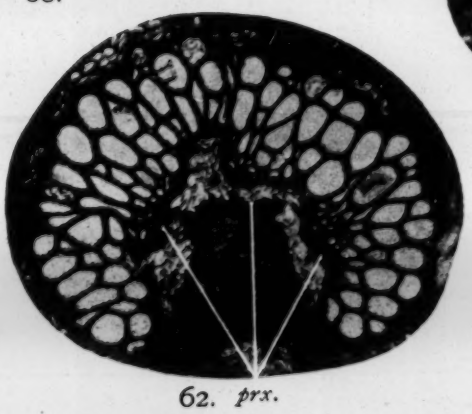


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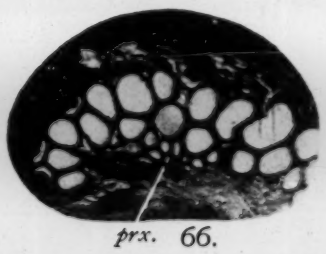


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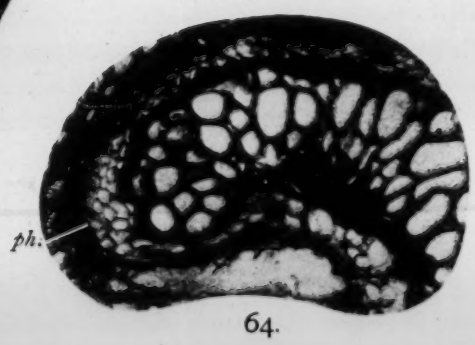


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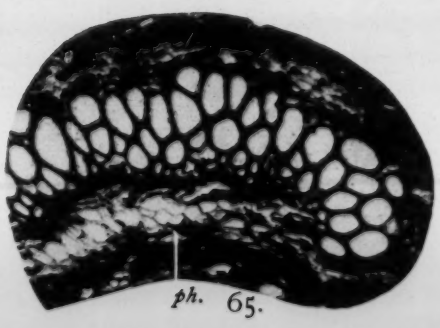


65.

R. Kidston, Photomic.

ANOMORRHŒA FISCHERI. Eichwald.

# XXIV.—A Monograph on the general Morphology of the Myxinoid Fishes, based on a study of Myxine. Part III. Further Observations on the Skeleton.

By **Frank J. Cole**, B.Sc. Oxon., Professor of Zoology, University College, Reading. *Communicated by* Dr R. H. Traquair, F.R.S. (With one Plate.)

(MS. received October 1, 1908. Read December 7, 1908. Issued separately February 18, 1909.)

The first and second parts of this work (7, 8), on the skeleton and muscles respectively, were published in the *Transactions* of the Society for 1905 and 1907. The third part would naturally have related to the viscera, and this, in fact, is in active preparation, but it is first necessary to amplify the description of the skeleton. Figs. 1 and 2 in my first part were based on dissections, which were executed very carefully, and the results checked by the examination of serial sections. It is, however, peculiarly difficult, and especially so in *Myxine*, to preserve the natural relations of the parts, and these drawings therefore exhibit the defects incidental to the method by which they were prepared. I mean by this, not that they are inaccurate, but that the inter-relationships of the parts could not be faithfully represented. Quite apart from this, however, it became necessary to re-draw these figures. A great part of this work is based on the investigation of serial sections, and especially on one large and complete series, carried as far back as the liver, which I succeeded in preparing after many failures. Anyone who has attempted to obtain a series of the head of a 25 cm. *Myxine* in which no sections shall have been lost, and each one flat and unbroken, will have realised that this has been no light task. All the section work centres round this one series, and it is hence important, for the purposes of co-ordination, that it should be possible to compare the charts of the vascular and nervous systems, which I am preparing, with similar charts of the skeleton based on the same series of sections. Therefore I plotted the two charts illustrating the present paper, and I think it will be found that these are not only necessary to the understanding of the future sections of the work, but are otherwise an essential feature of the whole. I also add some further notes on the anatomy of the skeleton on points which have been elucidated since the publication of Part I.

The expenses of this research have been defrayed by a grant from the Government Grant Committee of the Royal Society.

Simultaneously with the issue of my first part, an elaborate and important description of the micro-anatomy of the Myxinoid skeleton was published by Schaffer (28). In this memoir he states that the yellow-brown colour which the hard cartilage assumes after it has been in spirit is only superficial, and is due to a *post-mortem* imbibition of colouring matter from the blood. I have so far not found this discoloration supervene in formalin-preserved material, although Ayers and

JACKSON state that this preservative gives the cartilage a "pink or reddish tinge." SCHAFFER'S work is concerned very largely with the micro-chemical reactions of the various skeletal tissues of *Myxine*. The hard cartilage, he says, consists of the cartilage cell (*ct. c.*),* the cell capsule (*c. ct. c.*), the *Zellhof* (*s. g. s.*) exhibiting a concentric and radial structure and consisting of outer and inner portions with specific staining reactions, and an interterritorial ground substance (*c. sb.*). The staining reactions are as follows:—"Im allgemeinen kann man aber, wie gesagt, finden, dass bei dieser aufeinander folgenden Färbung mit einem sauren und einem basischen Farbstoffe die Kapsel den letzteren bevorzugt, während der Zellhof in seinem äusseren Umfang ausgesprochen oxyphil ist, in seinem inneren, an die Kapsel grenzenden einen gemischten Charakter zeigt" (pp. 168–9). "In allen diesen Fällen, in denen den Schnitten die Elektion gegenüber einem basischen und einem sauren Farbstoff gleichzeitig freigestellt ist, sehen wir also, dass die Kapsel sich mit dem basischen, die äussere Zone des Zellhofes mit dem saueren Farbstoffe färbt, während die innere gleichsam in einer Mischfarbe hervortritt" (p. 171). SCHAFFER also describes an interesting chondro-mucoid metamorphosis or degeneration of, and infiltration from, certain cells of the cartilage. The hard cartilage as a whole is divided into (p. 162) a middle zone, an outer zone, and a superficial apposition zone (p. 183). The latter consists of very flattened cells, the pericapsular substance corresponding to the interterritorial ground substance of the middle zone. From his study of the hard cartilage, and from a comparison of it with the cartilage of higher animals, SCHAFFER concludes: "Überblickt man die im Vorstehenden aufgeführten Tatsachen, so kann einem die auffallende Ähnlichkeit zwischen der territorialen Gliederung des harten *Myxine*-Knorpels und der gewisser typischer Hyalinknorpel der Säugetiere, wie sie durch die neueren Untersuchungen von MÖRNER, HAMMAR, TERRAZAS, HANSEN, MORAWITZ u. a. bekannt geworden ist, nicht entgehen" (pp. 209, 210). "Ich hoffe im vorstehenden überzeugend nachgewiesen zu haben, dass eine ziemlich einheitliche Auffassung der mannigfachen Formen des Knorpelgewebes möglich ist, wenn man von der klaren, leicht verständlichen territorialen Gliederung des harten Knorpelgewebes von *Petromyzon* und *Myxine* ausgeht" (p. 217).

The soft cartilage, according to SCHAFFER, corresponds to the cartilage which forms the gill cartilage of *Ammocœtes*, and exhibits as the cartilage matrix that characteristic slime-like substance described as "chondro-mucoid": "Geht man etwas näher auf *das mikrochemische Verhalten* des weichen Knorpels ein, so wird man bald sehen, dass die einfache Bezeichnung desselben als 'basophil' gegenüber dem vorherrschend 'oxyphilen' harten Knorpel nicht zutreffend ist, wenngleich er sich mit einer Reihe sog. basischer Farbstoffe charakteristisch färbt und gewisse 'saure' ablehnt" (pp. 226–7). Morphologically, the soft cartilage is not entirely identical with the gill cartilage of *Ammocœtes*, but varies with its functional necessities. It agrees best, however, with the latter at those places where it is of a more rudimentary character.

* These letters refer to fig. 3 of my first part.

Similarly, the histogenesis of the soft cartilage at these places resembles that of the gill and tail fin cartilages of *Ammocœtes*. "An den meisten übrigen Stellen lässt die Intercellularsubstanz des weichen *Myxine*-Knorpels, wie ich schon an andrer Stelle bemerkt habe, zweifellos eine Zusammensetzung ans interterritorialer Grundsubstanz (primärer Kittsubstanz) und sekundär eingelagerten Zellhöfen (Kapselsubstanz) erkennen. Trotzdem bleibt die gesamte Intercellularsubstanz stets spärlicher als im harten Knorpel und stellt dieselbe—mit Ausnahme der ebengenannten Stellen—vielfach ein Balkenwerk mit polygonalen Maschen dar" (p. 229). Elsewhere, SCHAFFER remarks that there occurs in the soft cartilage a true "interterritorial" substance, as in the hard cartilage.

SCHAFFER concludes his description of the soft cartilage with a discussion of the relationship between the soft cartilage and the hard. Can the soft cartilage pass over into the hard—must the hard pass through a soft stage, or is the hard cartilage from the beginning a separate and independent type of tissue? In *Ammocœtes* SCHAFFER repeats that the two kinds are not related, and that their points of junction are only secondary. In the Myxinoids the question is a more complex one, since the shuffling of the two kinds is much more in evidence, and, if independent, then the skeleton of the Myxinoids must consist of a greater number of originally separate elements than that of the Lampreys. It seems at first sight superfluous to argue about a matter which can only be definitely settled by a study of the development of the Myxinoid skeleton. SCHAFFER, however, definitely ranges himself against STUDNIČKA, who regards the distinction between hard and soft cartilage as an artificial one, and holds, on the strength of the *Ammocœte*, that the two kinds represent originally independent types of tissue. He says that though the soft cartilage of *Myxine* may microchemically and morphologically approximate to the hard, it is not transformed into it, and further that typical hard cartilage is distinctly separated by certain morphological peculiarities from the hard variety of the soft cartilage. Again, he refers to the sporadic occurrence of nests of cartilage in places where they can only represent a degenerating structure, and mentions one such between the second and third gills which consisted of a nodule of *hard* cartilage embedded in pseudo-cartilage. The point here seems to be that the nodule should have reverted to the soft stage if it had ever passed through it phylogenetically.

It appears to me hardly profitable, in the absence of embryological data, to enter into any discussion of SCHAFFER's views on the above question. I should like, however, to draw attention to one or two facts. It is unquestionably true that a broad fundamental pattern may be discerned in the distribution of the hard and soft cartilage, but it is also and equally true that that pattern does not depend on any *sharply defined* topographical distinction between these two tissues. For example, the anterior half of the forward rod of the hypophysial plate was, in the large old 45½ cm. *Myxine* on which my previous drawings of the skeleton were based, formed of hard cartilage. In young animals it consists entirely of soft cartilage, and in the 25 cm. Hag of my

present drawings there were a few scattered nodules of hard cartilage. Again, as regards the nasal capsule, which surely must be regarded as a whole and not as a complex of two or more parts, we may find it consisting (and especially the lateral plates) predominantly of hard cartilage (*cp.* fig. 1 of my first part); but it is coloured blue in my present figure, because in these sections it consisted essentially of soft cartilage with only a few nests of hard cartilage here and there (particularly in the anterior portion of the lateral plates). Without going further into this question, which must be discussed in a later section of the work, I may in the meantime point out that the *via media* between SCHAFFER and STUDNIČKA, *i.e.* that the various types of cartilage found in the Cyclostomes represent modifications of a single ancestral tissue, which was expressed in my first part, and which a careful perusal of SCHAFFER's latest paper does not disturb, represents a satisfactory solution of the difficulty, always pending a detailed examination of the embryogenesis of the Myxinoid skeleton. On this view, STUDNIČKA is wrong when he states that there is no real distinction between hard and soft cartilage, and SCHAFFER is also wrong in claiming that the distinction is an absolute one. Thus the hard cartilage would not *necessarily* pass through a soft cartilage stage. It should, however, be mentioned that on p. 247 SCHAFFER states that the pseudo-cartilage of *Myxine* is only a link in a long chain of tissues which begins with the skeletal tissues of Invertebrates and ends with the typical cartilage of higher Vertebrates.

With regard to the pseudo-cartilage, SCHAFFER says (p. 247): "Wir haben demnach hier ein Gewebe vor uns, welches manche Analogien mit der einfachsten Form echten Knorpelgewebes, wie es z. B. in den genannten Knorpeln von *Ammocœtes* und *Myxine* vorliegt, darbietet. Hier wie dort sehen wir verhältnismässig voluminöse Zellen, welche in ein Alveolenwerk dünnwandiger, membranen- oder kapselartiger Grundsubstanz eingeschlossen ercheinen. Die durch diesen Bau bedingten physikalischen Eigenschaften des Gewebes stimmen mit denen echten Knorpels ebenfalls überein, so dass die ältere Auffassung desselben als einer Form des Zellknorpels verständlich erscheint. Die genauere Untersuchung hat aber wesentliche Unterschiede vom echten Knorpelgewebe ergeben, so dass anderseits die Bezeichnung 'Pseudoknorpel,' welche Stadelmann für dieses Gewebe im Sesamknötchen der Achillessehne des Frosches aufgestellt hat, als vollkommen gerechtfertigt bezeichnet werden muss." He regards the envelope of the third segment of the basal plate as a perichondrium, although he points out that it is not a typical one. He also describes an infiltration of lime in the fibrous network of the pseudo-cartilage. At the friction area of the tendon of the copulo-glossus profundus SCHAFFER found in one animal a small nest of (apparently soft) cartilage. I have found the same thing in the tendon of the longitudinalis linguæ, where there is no friction area. In this connection SCHAFFER says (p. 249): "Aus diesen Beobachtungen scheint mir mit Sicherheit hervorzugehen, dass die Zellen des blasigen Stützgewebes [pseudo-cartilage] auch eine etwas andre biologische Bedeutung besitzen als echte Knorpelzellen, oder dass wenigstens die

mechanische Leistung des blasigen Stützgewebes nur teilweise jener des echten Knorpelgewebes entspricht. Damit haben wir auch die genetische oder besser gewebsbildende Verwandtschaft beider Gewebe berührt. Dieselbe findet darin ihren Ausdruck, dass gelegentlich Bildungszellen des blasigen Stützgewebes sich in echte Knorpelzellen umwandeln können." Again (p. 250), he says: "Besonders an ersterer Stelle [tendon of the longitudinalis linguæ] handelt es sich also um eine vollständige Analogie mit den Sesamknötchen in verschiedenen Sehnen bei Anuren und Reptilien und müssen hier diese blasenförmigen Zellen der *Myxine*, wie bei den genannten Tiergruppen, als eigentümlich metamorphosierte Zellen des fibrösen Gewebes angesehen werden."

Near the centre of the notochord of *Myxine* is found usually what is known as the "fibrous core" (*cp.* fig. 1, Part II.). As discovered by v. KÖLLIKER and v. EBNER, this consists of chordal cells elongated in a longitudinal direction and having relatively thick walls. SCHAFFER (28, pp. 199–200) draws attention to a somewhat similar structure in the external bar of the anterior segment of the basal plate, in the middle of which exists a mass of ground substance lodging very flattened and modified cartilage cells. This is compared with the fibrous core in the skull chorda of the *Ammocœte* and in the chorda of the larval eel, and is said to be due to the encroachment of the peripheral chordal cells producing a simplification and compression of the cells in the axis.

The cranium of *Bdellostoma* has been described by Miss JULIA WORTHINGTON (36). It is a tough, flexible capsule of dense fibrous connective tissue lined with endothelial cells, the walls being thinner at the cephalic than at the caudal end. The fibres are very thick and tough, and may be either straight or wavy. "At the hind end of the medulla, ventral to it, and just anterior to the notochord, lying between the layers of the fibrous capsule, is a thick plate of cartilage, connecting the cartilaginous ear capsules. This is the only cartilage found in the cranium." Assuming that this does not refer to the parachordal cartilage, I find no such plate in *Myxine*, nor, of course, has it anything to do with the infiltrating cartilaginous substance wrongly described in the cranium by J. MÜLLER. The shape and relations of the cranium to the skeleton in *Myxine* are shown in fig. 1 (*cr.*).

As I have stated above, the boundaries of the soft and hard cartilage do not admit of strict definition, although a fundamental pattern unquestionably exists. A comparison of the figures in my first part with those now given, and also of a number of preparations and series of sections, shows that whilst some regions consist always of hard cartilage and others of soft, there are places again which appear to constitute a kind of neutral ground, and in which the distribution of the two kinds of cartilage certainly varies. Such places are, for example, the hyoid arch (*hy.*), the nasal capsule (*n. c.*), and the hypophysial plate (*h. p.*). Further, at the numerous places where the two kinds meet, the union is so close and intimate as to knit the skeleton into a connected whole without the presence of joints or sutures. It is useless to speculate

on the component elements of the skeleton until its developmental history has been worked out. STOCKARD (30), the only writer who has published on the development of the Myxinoid skeleton, makes no reference to this point.

In fig. 3 of my first part a cartilage cell is shown containing four nuclei, and others with two each. This must not be confused with one of the phases of chondro-mucoid degeneration of the cartilage cell described by SCHAFFER, in which spaces appear in the sarcode containing chondro-mucoid granules. These spaces with their contents simulate the appearance of nuclei, but may easily be distinguished from them.

The parachordal cartilages (*pc.*) represent a chondroidal deposit between the elastica externa and the skeletogenous layer of the notochord. This deposit is generally of a uniform shape, but varies in the extent to which it may be prolonged backwards. The posterior extension usually follows three lines—a median ventral one and a pair of dorso-lateral ones. Occasionally the parachordal dies away in detached nodules of cartilage. This is shown on the right side of fig. 2.

The hypophysial plate (*h. p.*) consists predominantly of soft cartilage, but the anterior half of the forward handle may be formed of hard cartilage, and probably in all cases there are nests of hard cartilage here and there in this part of it. The posterior end of the central plate is usually more or less ragged, and the posterior handle is always fenestrated—all the fenestrations being correctly shown and located in fig. 2. Owing to its V shape, its true width cannot be shown in the figure, being, of course, much greater than appears. The outline in fig. 2 was obtained by measuring across the tips of the V.

The inferior lateral cartilage (*i. l. c.*) may terminate in a pointed rod behind the second branchial arch, as shown in fig. 1, Part I.; but more usually there is only a posterior blunt projection here, and a corresponding anterior one into the fourth fenestra ($f.^4$). On the right side of fig. 2 is shown a small perforation at this point.

In my first part it is stated (p. 763) that the lower division of the second "branchial" arch ($br.\ a.^2$) is not always present. It was not found by PARKER, but is figured by P. FÜRBRINGER and NEUMAYER, and SCHAFFER (28, p. 242) apparently never found it wanting. As stated in my previous paper, it was present in all my series of sections without exception. Owing to its close connection with the posterior segment of the basal plate, it is not usually noticed in dissections unless specially looked for, and I now feel disposed to regard my former statement as erroneous, and to believe that the lower division of the arch is invariably present. I feel the less certain about this, however, since I am able to record one surprising variation in this arch. AYERS and JACKSON describe in *Bdellostoma* for the first time a fusion between the posterior extremity of the lower division and the inferior lateral cartilage, thereby eliminating the break in the course of the arch present in *Myxine*. This was not found in *Bdellostoma* by either J. MÜLLER or PARKER, but since my first part was written I have found it once in *Myxine*. It is interesting to record this important variation, since it must be a very rare one, nor is it one that could be easily overlooked.

In my large series of sections there are some independent nodules of soft cartilage in the "branchial" arch region which may be mentioned here. One of these is situated dorsally in the neighbourhood of the free extremity of the superior lateral cartilage (*s. l. c.*), and was only present on the left side (*cp.* figs. 1 and 2). Another is ventral, is associated with the tip of the lower division of the second "branchial" arch, and is present on both sides, as shown in the figures, although more marked on the right. As we know from STOCKARD'S work (30) that immediately posterior to the mouth cleft there are three pairs of clefts which disappear during embryonic development, it is possible that these remnants may represent a third "branchial" arch.

The so-called "hyoid" arch (*hy.*) is more accurately figured in the present part than in my first. The forwardly projecting ventral plate which was formerly referred to as a variation I now believe to be a normal structure. It consists of soft cartilage, is very thin, and strips off with the slightest tension in cleaning up the skeleton. The ventral edge of the hyoid may also be ragged—in the charts this is more noticeable on the left than on the right side (*cp.* fig. 2). The projections into the third and fourth fenestræ are pointed, and it is interesting to note on the right side that the "hyoid" arch, owing to a postero-dorsal extension of the third fenestra, only remains connected with the superior lateral cartilage by a narrow bridge (fig. 2). It is possible this may represent one of the breaks present in the embryonic skeleton.

The anterior fusion of the palatine bars (*pl.*), known as the palatine commissure, is coloured red in fig. 2, although it consists by no means entirely of hard cartilage. There is, in fact, a considerable infiltration of soft cartilage here, and as PARKER describes a definite tract of soft cartilage in the commissure which he calls the "ethmoidal region," it is possible the soft infiltration may appear on the surface as a well-defined area in some specimens. In his sections PARKER colours the "ethmoid" as hard cartilage, and explains that the sections being taken from an older animal the hard cartilage had replaced the soft.

I have previously referred (7, p. 765; 8, pp. 694–5) to a median pad of soft pseudo-cartilage immediately in front of the palatine commissure and the median dorsal tooth. Although the two palato-ethmoidalis profundus muscles are closely opposed to this pad, they are not, I believe, as I formerly stated (7), attached to it. SHAFFER refers to this structure in the following terms (p. 250): "Als selbständige knorpelige Masse findet man dieses Gewebe [pseudo-cartilage] weiter in Form eines horizontal und quer gelagerten Stäbchens vor und unter der vorderen Vereinigung der Gaumenleisten, welches sich caudad in zwei längliche, im Querschnitt rundliche Fortsätze gabelt; letztere umfassen die Basis des Gaumenzahns."

The cornual cartilage (*c. c.*) exhibits a feature which I believe to be always present, but which has hitherto escaped attention (*cp.* 7, p. 766). I refer to the backward and inward projection from the cartilage near its tip, and which is connected by a short, stout ligament with the lateral labial cartilage shortly behind where the latter fuses with the cartilage of the third tentacle (figs. 1 and 2). J. MÜLLER figures a connection

between the cornual cartilage and the lateral labial here, but says nothing as to its nature. NEUMAYER did not find it at all. PARKER and AYERS and JACKSON figure a slight projection on the cornual cartilage, and this, I believe, represents the place where the projection was torn off in cleaning up the cornual cartilage, as happened in my own case. POLLARD (18), in constructing wax models from serial sections, was bound to see it, and we consequently find it in his fig. 11, but he makes no reference to this feature in his description. It may possibly represent the remains of a cartilaginous connection between the cornual cartilage and the lateral labial.

The nasal skeleton is perhaps chiefly peculiar on account of the structure of the posterior transverse bar of the olfactory capsule (*p. t. b.*). This sends downwards and backwards a cylindrical rod (*h. p.'*), which I formerly believed (7, p. 768) was a connection between the nasal capsule and the hypophysial plate. And so it is; but it is something more. When studying the velo-quadratus muscle my attention was drawn to this rod again (8, p. 721), and the origin of the muscle at once suggested that the rod is really a connection between the nasal capsule *and the trabecula*, and that it merely fuses with the hypophysial plate on its way to the trabecula. This is a typical illustration of how a dissection, even if carefully carried out, just fails to result in that refined degree of accuracy necessary for the right conclusion. A comparison of fig. 2 of my first part and fig. 2 of the present one will illustrate this point. NEUMAYER'S fig. 4 should also be consulted.

The nasal capsule varies in histological structure. It is really a mixture of soft and hard cartilage, and either may predominate perhaps according to the age of the animal. The large lateral plate, however (*l. p.*), always contains more hard cartilage than any other part of the capsule.

As previously described, the lateral labial cartilage (*l. l. c.*) exhibits a very curious sigmoid twist before fusing with the basal plate. I never realised, however, how considerable this twist was until I plotted fig. 2. It cannot be shown in a lateral view. POLLARD does not appear to have noticed it, and PARKER missed it in his dissections, but it appears in his sections as the "oral barbel"—which is further forward than where he figures it, nor could it have been in that position. Similarly, it is not described by J. MÜLLER and AYERS and JACKSON. The only writer who has noticed it is NEUMAYER, in whose fig. 4 this mysterious twist is even more marked than in my fig. 2. Its meaning I am unable to explain.

In the neighbourhood of the sigmoid twist on each side and embedded in the soft pseudo-cartilage at the anterior end of the basal plate is a discrete piece of soft cartilage (figs. 1 and 2). The two pieces form a distinct pair (*cp.* fig. 2), and appear to have some significance.

The cartilage of the fourth tentacle (*4*) consists of both the hard and soft varieties. The former is confined to that part of the cartilage situated within the contour of the body (the internal rod), and in the old specimen on which my former figures were based this rod was formed largely of hard cartilage. In the present specimen, however,

there were only a few nests of hard cartilage here and there, and hence the whole of it is coloured blue in figs. 1 and 2.

With regard to the basal plate, reference must first be made to SCHAFFER's description and figures (28), published almost simultaneously with my own. His results are practically identical with mine, the only differences being such as may easily be explained by individual variation. Thus, for example, he does not describe the median zone of soft cartilage in the middle segment extending from one end of it to the other, although I have found it do so both in dissections and serial sections. He says, in fact: "Die Knorpel der zweiten Reihe [middle segment] bilden ebenfalls ein einheitliches Stück, welches allerdings in der Medianlinie eine weichknorpelige Naht besitzt, welche jedoch den rostralen Rand des hinteren Mittelstückes nicht erreicht" (p. 242). SCHAFFER states that the pseudo-cartilage "rails" (7, pp. 772–3) may be regarded as independent skeletal pieces, since they are enclosed in a fibrous membrane: "So bildet es an der dorsalen, konkaven Fläche des rinnenförmigen 'Zungenbeins' dort, wo es bereits hartknorpelig geworden ist, zwei dünne, leistenförmige Aufsätze, welche von der Masse des Zungenbeinkiels entspringend, zunächst über den freien, dorsalen Rändern desselben verlaufen, dann in die Rinne des hartknorpeligen Zungenbeins hineinrücken und hier parallel gegen den rostralen Rand nach vorn ziehen, um sich dort miteinander und mit dem kissenartigen Überzug zu vereinigen. Sie dienen zur Vertiefung der Rinne, in welcher, wie in einer Schlittenbahn, die Sehne des Retractor linguæ [and also the dental apparatus] gleitet" (pp. 249–250).

The relative proportions of the three segments of the basal plate ($b.p.^1$, $b.p.^2$, $b.p.^3$) do not appear to vary very much. Thus, to take three cases at random, omitting the anterior pad of pseudo-cartilage, and regarding the whole plate as a unit of measurement, we get the following results from SCHAFFER's figures (A), from the figure in my first part (B), and from my large series of sections (C). The three segments of the basal plate are taken from before backwards. A, ·19, ·21, ·6; B, ·181, ·166, ·652; C, ·194, ·184, ·621. It is thus seen that the anterior segment is the most constant.

The posterior segment of the basal plate ($b.\ p.^3$), differing so markedly from the others, has attracted much attention. AYERS and JACKSON (2, p. 205) state that "it is quite evident that the third segment is not a true cartilage, but is formed by a chondroidal modification of the tendon of the 'constrictor' muscle [copulo-copularis]." Again (3, p. 10): "Of these, the posterior is composed, not of true cartilage, but of a chrondroidal tissue, and is certainly not to be considered as homologous with any part of the visceral arches. It is merely a condensation of the tendinous tissue in the median ventral raphe of the constrictor musculi mandibuli." SCHAFFER (26) regards the posterior segment as a true sesamoid formation in the tendon of the retractor linguæ (longitudinalis linguæ). I presume SCHAFFER means the copulo-copularis, since it is obviously impossible that the retractor muscle can have anything to do with the basal plate; but he repeats the statement in a later paper (27). Assuming, as appears to me

probable, that SCHAFFER really has in his mind the same muscle as AYERS and JACKSON, there seems, as I formerly thought (7, p. 756), some reason for this view. The muscle and the third segment certainly appear to be merely parts of one whole, but an intimate examination of the muscle is entirely against this assumption. The mere fact that the copulo-copularis is a *transverse constrictor* muscle, of course without a tendon, is in itself sufficient, since I take it that no conversion of muscle fibre into pseudo-cartilage is asserted. There is, in fact, no evidence to show that the muscle was ever more extensive than it is now, and we must therefore question AYERS and JACKSON's suggestion until it is better supported.

The dental apparatus is regarded by AYERS and JACKSON, not as a tongue, but as the detached lower jaws. SCHAFFER, in his latest paper, dissents from this view, and compares it with the tongue of the eel and the hyoid bone of Amphibia. He therefore approves of the old view that the structure is a tongue. The basal plate he regards as a strongly modified lower-jaw apparatus (MECKEL's cartilage). Since SCHAFFER's paper was published, STOCKARD has provided us with some evidence on this question. From a study of the development of the visceral clefts, STOCKARD decides in favour of AYERS and JACKSON, and the view therefore now rests on something more than conjecture. Unfortunately, STOCKARD does not describe the development of the skeleton of this region, and it is to be hoped that he will complete the case by a description of the skeletal parts of his embryos at an early date.

SCHAFFER's recent description of the dental apparatus agrees largely with mine. He does not, however, mention the small foramen of the anterior arch (*a. d. p.*), nor the posterior external process of the same (*a. d. p.'*). The posterior arch (*p. d. p.*) he figures as composed of hard cartilage, but with a small cylinder of soft cartilage at its centre (*cp.* 7, fig. 7). In my sections only the posterior narrow part of the posterior arch, *i.e.* just where it fused with the anterior arch, consisted of hard cartilage. The rest of the bar was formed of soft cartilage, with, however, in the stouter parts, a fairly considerable infiltration of hard cartilage (fig. 1). Another point of difference is that SCHAFFER finds the whole of the space between the anterior and posterior arches occupied by pseudo-cartilage, whereas I find only a slight deposit there. Both the protractor and retractor tendons, as each approaches its respective arch, are invaded by soft pseudo-cartilage, and in the latter case there are nests of soft cartilage also. The skeleton of the dental apparatus may therefore be sesamoidal.

The only point I wish to add to my previous description of the skeleton of the velum or pharyngeal valve relates to the external lateral velar bar (*e. l. b.*). The head of this rod is formed of hard cartilage, and is connected by a bridge of soft cartilage with the inferior process of the pterygo-quadrate where the latter fuses with the hyoid arch. In the sections, however, the opposite angle of the head was formed of soft cartilage, and as this was present on both sides it seems something more than the sporadic occurrence of a small tract of soft cartilage (*cp.* figs. 1 and 2).

At the posterior end of the inferior chondroidal bar, and above it, there is a small

patch of soft pseudo-cartilage in the sections, and also the extreme posterior tip itself is composed of soft pseudo-cartilage. This is of interest in view of AYERS and JACKSON'S statement, which I venture to doubt, that this bar consists entirely of pseudo-cartilage in *Bdellostoma*. The superior bar does, as SCHAFFER and myself have pointed out.

As confirmed by STOCKARD, the branchial skeleton of *Bdellostoma* is entirely extra-branchial in all cases except that of the œsophago-cutaneous duct (and the one described below), where, as in *Myxine* (7, fig. 11), the cartilage extends to, and slightly spreads out on, the œsophagus. STOCKARD, however, believes that the Myxinoids "are contrasted with fishes as having extra branchial skeletons on rather flimsy grounds" (30, p. 509), pointing out that the extra-branchial position may well be secondary owing to the development of pouched gills, the pouches appearing before the cartilages and preventing them spreading on to the gut as in the case of the ductus œsophago-cutaneus. STOCKARD describes the disappearance of three pairs of gill clefts behind the mouth — a hyomandibular pair and two pairs of post-hyomandibular—a fact which must be reckoned with in working out the morphology of the Myxinoid skeleton. In this connection I may point out that SCHAFFER describes a rudiment of soft cartilage on the right side of the œsophagus immediately behind the gills (28, p. 236, fig. 25). I find this also in my large series of sections. It extends from section 3095 to 3110, and commences at about opposite the posterior margin of the external opening of the ductus œsophago-cutaneus, and therefore immediately behind the gill region. It is embedded in the submucosa of the œsophagus (of course, under the constrictor muscle) at the middle of its lateral surface. The interesting feature of this small piece of cartilage is that it undoubtedly corresponds to the œsophageal rod on the left side which I have called $x^1$ (Part I., figs. 11 and 13). It is exactly opposite this rod in the sections, and in the same layer of the œsophagus, but extends eight sections behind it. There is thus a visceral portion of the branchial skeleton on the right side as well as on the left, which coincides with STOCKARD'S views mentioned above.

*September* 10, 1908.

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## EXPLANATION OF THE PLATE.

### Reference Letters.

*a. d. p.* Anterior arch of the dental plate.
*a. d. p'.* Posterior external } processes of above.
*a. d. p".* Posterior internal }
*a. t. b.* Anterior transverse bar of the nasal capsule.
*a. t. v. b.* Anterior transverse velar bar.
*au. c.* Auditory capsule.
*au. f.* Auditory foramen.
*b. p.*$^{1-3}$ Anterior, middle, and posterior segments of the basal plate.
*br. a.*$^{1}$ First "branchial" arch.
*br. a.*$^{2}$ Second "branchial" arch, consisting of separated upper and lower divisions.
*c. c.* Cornual cartilage.
*cr.* Membranous cranium.
*d. t.* Median dorsal tooth.
*e. b. p.'* External bar of the anterior segment of the basal plate.
*e. l. b.* External lateral velar bar.
*f.*$^{1-4}$ The four fenestræ of the skull.
*h. p* Hypophysial plate.
*h. p.'* Rod connecting above with the posterior transverse bar of the nasal capsule.
*hy.* "Hyoid" arch.
*i. b. p.'* Internal bar of the anterior segment of the basal plate.
*i. l b.* Internal lateral velar bar.
*i. l. c.* Inferior lateral cartilage.
*l. l. c.* Lateral labial cartilage.
*l. p.* Lateral plate of the nasal capsule.
*n. c.* Nasal capsule.
*nt.* Notochord.
*pc.* "Parachordal" cartilage
*p. d. p.* Posterior arch of the dental plate.
*pl.* "Palatine" bar.
*p. q.* "Pterygo-quadrate."
*p. t. b.* Posterior transverse bar of the nasal capsule.
*p. t. v. b.* Posterior transverse velar bar.
*s. l. c.* Superior lateral cartilage.
*sn. b.* Subnasal bar.
*sp. c.* Membranous neural tube.
*tr.* Trabecula.

Fig 1. Reconstruction from serial sections of the left side of the skull of a 25 cm. Hag. $\times 14\frac{2}{3}$. Tentacular cartilages and the rings of the nasal tube numbered from before backwards. The colours and shading indicate the different kinds of cartilage, and also the staining reactions of the same with Mann's methyl-blue-eosin: hard cartilage, red; soft cartilage, blue; hard pseudo-cartilage, blue (dotted); soft pseudo-cartilage, uncoloured and obliquely striated.

Fig. 2. Reconstruction from serial sections of the dorsal surface of the skull of the same Hag. $\times 14\frac{2}{3}$. Tentacular cartilages numbered from before backwards. The "branchial arches" have been displayed for the sake of clearness, and this involves an artificial lengthening of the first branchial arch, and also a lateral displacement of the external lateral velar bar. This, however, does not affect the correct delineation of the parts in the longitudinal plane, and hence the two figures may be strictly compared. Nasal tube and capsule removed and the dental skeleton not shown. Tentacular apparatus seen in perspective, and, apart from the sigmoid twist, cannot be so accurately shown as in a lateral view. Anterior pseudo-cartilage cap of the basal plate omitted, nor can the bending of the hypophysial plate be shown. Colours, etc., as in fig. 1.

It should be pointed out here that in Part I., owing to a misunderstanding with the lithographer, fig. 16 was laid down on the stone the wrong way. The figure is quite accurate, but the sides must be reversed. If the plate be held up with the figure towards the light the correct ventral view is obtained, the structures on the observer's right belonging to the animal's left, and *vice versa*.

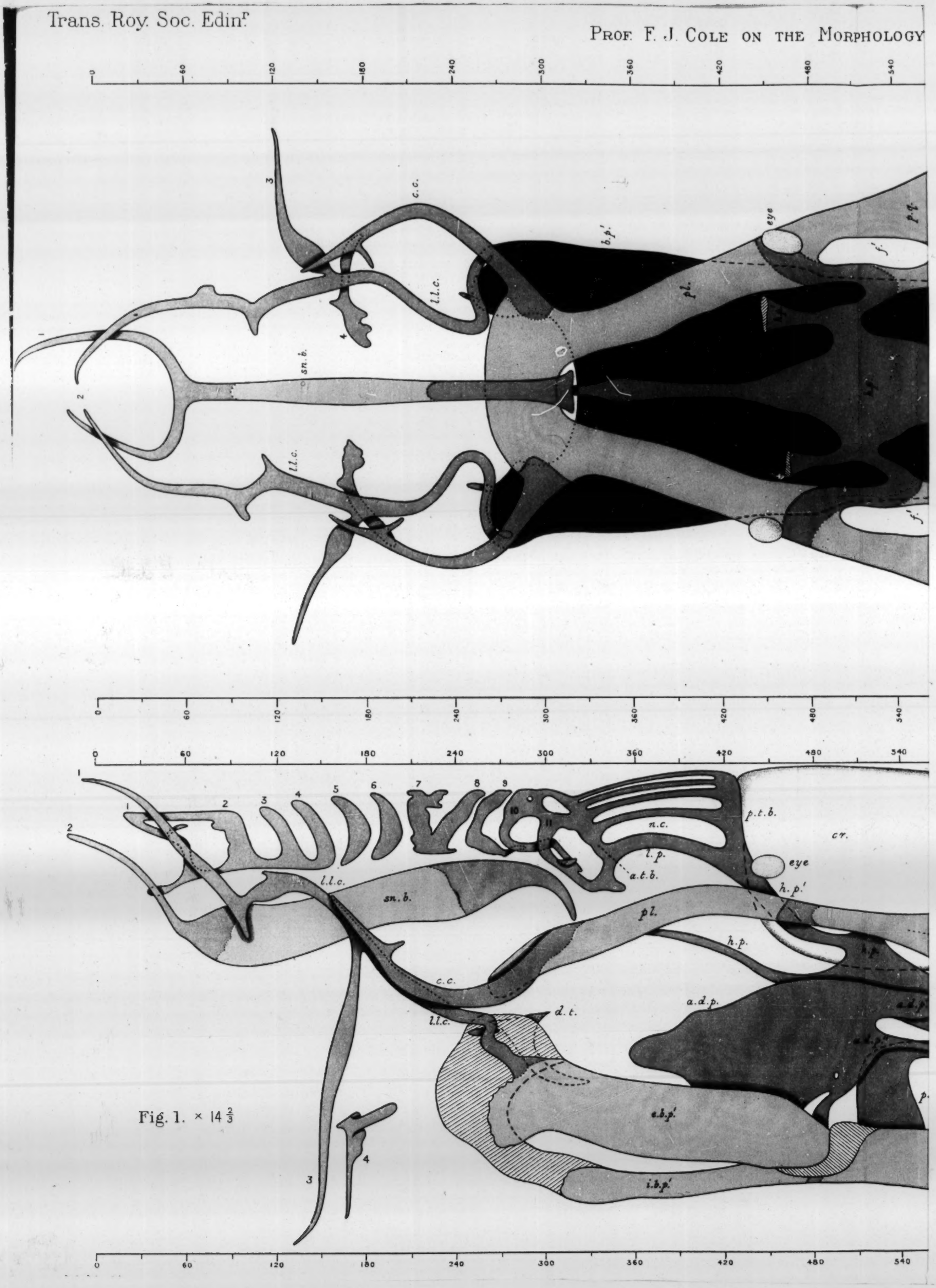


Fig. 1. × 14 $\frac{2}{3}$

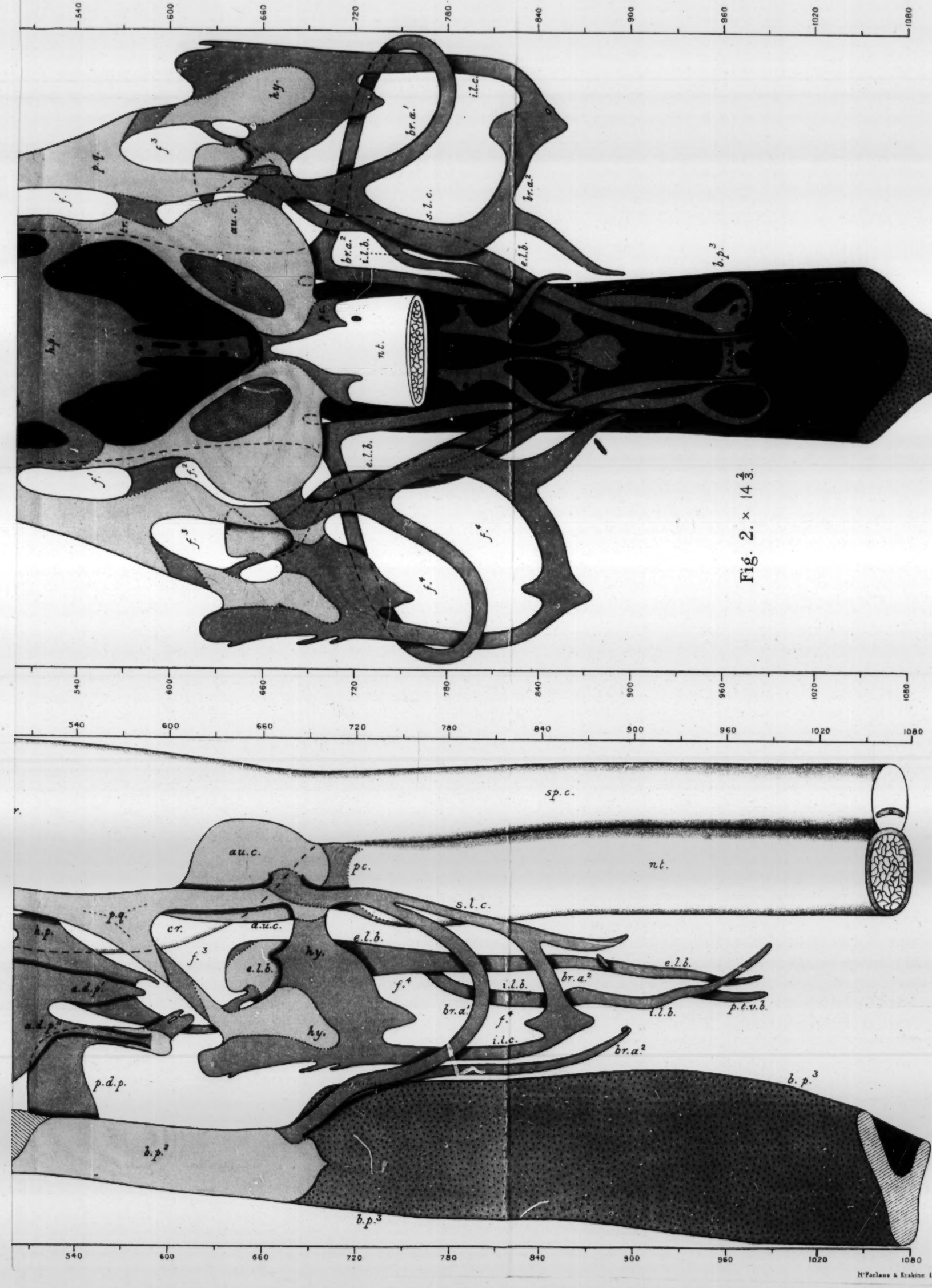


Fig. 2. × 14 2/3.

M'Farlane & Erskine Lith Edin.

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